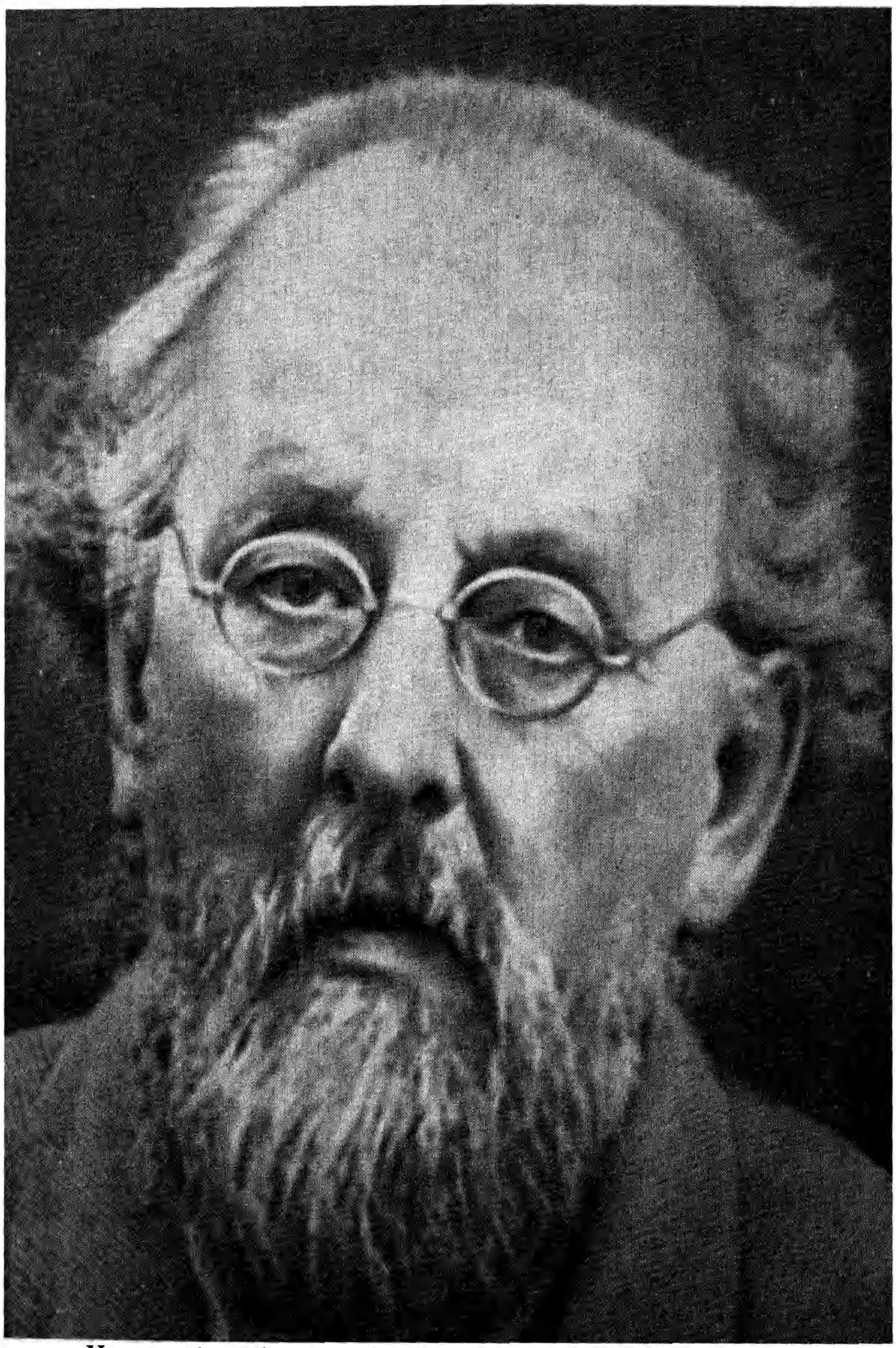
K.E. TSIOLKOVSKY

THE CALL OF THE COSMOS



Konstantin Eduardovich Tsiolkovsky (1857-1935).
Photograph by V. V. Assonov, 1920

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FOREWORD

Taken as a whole, this book makes interesting, even fascinating reading. Tsiolkovsky's stories are of tremendous interest and urge us to ponder over the many purely specific problems of space travel. They will, undoubtedly, increase the number of enthusiasts in this branch of science and technology. His "On the Moon", "Outside the Earth" and other stories afford hours of entertainment and leave a lasting impression.

Illustrated here is the world outlook of Konstantin Tsiolkovsky, original thinker, self-taught scientist, founder and keen enthusiast of space travel. Though man is bound by every fibre to his home-planet, Tsiolkovsky argues that he stands to gain immeasurably by gradually conquering space. Life in space, where there is no acceleration of gravity in relation to manned spacecraft, or even on such objects as the Moon or the asteroids, where the gravity is negligible compared with the Earth's, presents tremendous advantages, Tsiolkovsky claims, since with the same effort it is possible there to accomplish an incomparably greater amount of work. In addition, in the absence of disease-producing germs and drawing on the Sun's continuous radiation, it will be possible to cultivate in artificial hothouses with temperature control and air-conditioning, various kinds of plants, which provide food for a human population and also consume the excreta of animal organisms.

The achievement of this balance between animal and plant life on mammoth space rockets, a balance which would make possible space journeys of indefinite duration, provided the consumption of solar energy is controlled, presents an extremely interesting idea that should be closely examined with a view to the possibility of actually putting it into practice.

One may also agree with Tsiolkovsky in thinking that life will develop and prosper wonderfully in the absence of gravity pull as well and that for animal organisms atmospheric pressure can be much lower than what is usual and normal on the Earth. What he has to say about the different apparatus for making rocket travel comfortable in the absence of gravity, is most absorbing.

His descriptions of lunar landscapes, and journeys on the Moon, his fantastic stories about leaping lunar animals or beast-plants which either hide in crevices or try to keep abreast of the Sun to escape the approaching cold of the lunar nights, are most entrancing. Even these fantastic stories seem quite in place, because, for all their absolute improbability, they soften the picture we have of the harsh and rigorous natural conditions on the Moon.

However, Konstantin Tsiolkovsky lets his imagination run away with him, when he begins to describe the imaginary life of intelligent creatures on Mercury, Mars, the asteroids and other planets. Consequently, "Life in Space", "On Vesta", "Mercury", "Mars", "The Asteroids" and several other stories are fantasies of the first water, and where mention is made of intelligent beings on planets and asteroids no worthwhile information is desirable. Stories of this kind include his "Island of Ether"—about the structure and evolution of the Universe. Like the physicists of the nineteenth century, the author assumes that there exists "light ether" which, in his opinion, does not extend far beyond the limits of the material Universe accessible to us. Thus, in his opinion, our system of galaxies must be hopelessly isolated from other similar systems, as in

the absence between them of an ether medium capable of transmitting light, they must be totally inaccessible to observation. These arbitrary assertions—and this should be emphasised—do not at all coincide with Tsiolkovsky's general outlook, since he considered that there were no limits to our cognition of the infinite Universe.

And even those of Tsiolkovsky's writings, which are acceptable from the scientific point of view, contain several errors to which attention should be drawn.

In the first place, Tsiolkovsky does not sufficiently take into account that even in the case of diminished gravity the same inert mass remains, to which the same force must be applied to impart a definite acceleration as that applied on the Earth. Further, he overestimates the possibility of protecting a living organism from the excessive gravity which occur, for instance, during rocket acceleration, by immersing the living organism in an air-tight water bath. It is true, as Tsiolkovsky indicates, that the immersed organism would scarcely feel any violent blows on the outside of the vessel. But it would certainly feel intensive deceleration or acceleration of the vessel as a whole, and this might even prove fatal. The author completely underestimates the danger of collisions with meteorites and his descriptions of the way one might catch approaching bolides from the spacecraft, using something like a butterfly net, are most curious and can be attributed to his own typical brand of humour. Because in actual fact every time one of the host of micrometeorites whirring through space hits a spacecraft, it produces a minor explosion and is sure to dent the plating of the spaceship. These direct hits which should occur extremely often would almost immediately destroy the external green-house suggested by the author, which is shielded from its cosmic environment only by thin glass panes. Even far from the Earth, where its gravitational pull exerts almost no influence, the relative speed at which the meteorite collides with the spacecraft will nevertheless be of

the order of several kilometres, even tens of kilometres, a second. Hosts of meteorites thus would constitute a considerable danger to the safety of the spacecraft.

Various factors in some of Tsiolkovsky's writings are occasionally wrongly appraised. For instance, he points out several times that the temperature in the focus of mirrors concentrating the Sun's rays of a definite intensity will reach 6000°C. Purely theoretically a temperature of this order is conceivable only when the Sun's angular dimensions are magnified by mirrors to the dimensions of a complete sphere which, in practice, is not possible.

In accordance with the notions current at the time his stories were written, Tsiolkovsky speaks about each star being surrounded by a family of planets and all these planets being inhabited irrespective of their temperatures and other physical conditions. In his opinion—to which, incidentally, other authors have frequently subscribed—the living organism can be composed of any kind of elements able to produce liquid compounds at a given temperature. There is not even the slightest mention of the unique part played in the structure of the living organism by compounds of carbon with oxygen, hydrogen and also nitrogen, which require absolutely specific, strictly defined conditions. Neither did Tsiolkovsky think an atmosphere indispensable for organic life, presuming that organisms can produce and subsist on their own micro-atmospheres. There is no need to show the completely fantastic nature of such ideas.

Tsiolkovsky rendered a great service in so zealously advocating attempts to conquer outer space. But his fantasies in this direction knew no limits. He wanted to emphasise that mankind will of necessity migrate to other planets circling around some other sun, when our own Sun will have greatly cooled, which he thinks may happen in several million years from now. Of course, in Tsiolkovsky's time the gravitational energy of compression was thought to be the sole means by which the Sun maintained

radiation. However, to think today that the Sun may cool, in the direct sense of the word, is out of the question. It may, of course, ultimately pass into the category of white dwarf stars, which though of unusual density and having insignificant radiation, nevertheless have a high internal temperature. This process will require not millions but at least several thousands of millions of years. In some of his writings Tsiolkovsky suggests that the populations of the numerous planetary systems in various parts of the Universe establish associations or alliances of mutual assistance for promoting migrations to the most suitable planets, in order to avoid the dangers arising from their own suns "going out of commission". Here Tsiolkovsky reaches the extreme limits of fantasy.

Actually life in outer space should be viewed as a rare exception, and not a universal rule. However, this in no way minimises the vast scientific and practical importance of Tsiolkovsky's ideas about space exploration, on the threshold of which we now stand as a result of the tremendous Soviet scientific and technical achievements that have now ushered in a new era in the history of mankind.

The break through into space is proceeding along much the same lines as those which Tsiolkovsky forecast with such extraordinary insight so many decades ago. Tsiolkovsky was a most unique person and everything associated with him is of great interest. So though many of his statements are unacceptable today, they still serve as the best possible illustration of the fact that Tsiolkovsky was more than a designer of jet engines. In his dreams and scientific fiction he was already beginning to live in space.

ACADEMICIAN V. G. FESENKOV

Moscow, October, 1960

ON THE MOON

A Tale of Fantasy

I

I woke up, and, as I lay in bed, pondered over the dream I had had. I had dreamt I was bathing, and this dream of summer bathing was particularly pleasant, since it happened to be winter.

But it was time to get up.

I stretched myself and sat up in bed. How easy it was! Easy to sit, easy to stand. What can have happened? Was I still dreaming? I felt I was standing so lightly, that I might have been up to my neck in water. My feet hardly touched the floor.

But where on earth was the water? I could see none. I flourished my arms about: but I felt not the slightest resistance.

Was I dreaming? I rubbed my eyes; everything was just the same.

How odd!

But I had to get dressed.

I moved chairs, opened wardrobes, took out my clothes, lifted various objects and—I could not understand a thing!

Have I grown stronger? Why was everything now so ethereal? Why could I lift objects which I could not shift before?

No! These feet, these arms, this body could not be mine! Mine were always heavy and moved with difficulty.

How was it that my arms and legs were now so strong?

Could it be that some force was drawing me and everything else upwards and so lightening my work for me? But in that case what a strong pull it was exerting! A little more and it seemed to me that I would bump against the ceiling.

And why was I leaping instead of walking? Something was pulling me in the direction opposite to gravity, tensing my muscles and making me leap.

I could not resist the temptation, I jumped.

I seemed to have ascended rather slowly and descended equally slowly.

I leapt higher, and looked round the room from a fair height. Ouch! I knocked my head against the ceiling. The rooms are high-ceilinged and the concussion was unexpected. . . . I decided to take more care in future.

The yelp I gave awoke my friend. I watched him turn over and, a little later, hop out of bed. And I saw him make the same spectacle of himself as I, all unawares, had just made of myself. In fact, I derived the greatest satisfaction from watching his rolling eyes, his comical postures and the unnatural agility of my friend's movements. His odd exclamations, so like mine, amused me.

I gave my physicist friend time to exhaust the supply of surprises; then I asked him to solve just one question: what had happened? Had we grown stronger or had the gravity diminished?

Both conjectures were equally astounding. But one becomes indifferent to everything once he grows accustomed to it. My friend and I had not yet reached that stage, but we already wanted to know what was at the bottom of it all.

My friend, accustomed to analysing problems, soon sorted out the mass of phenomena that had stunned and confused my mind.

"We could use a dynamometer or spring balance," he said, "to measure our muscular power and discover whether it has increased or not. Watch me press my feet

against the wall and pull at the dynamometer hook. As you see, it is five poods.* I haven't grown any stronger. You can do the same, and you'll also see that you have not become a Hercules."

"How can I agree?" I objected, "when the facts are against it? Just explain why I can lift the end of this bookcase, though it weighs at least 50 poods? At first I imagined it was empty, but when I opened it, not a single book was missing. And while you're about it, explain how I managed to leap to a height of five arshins."**

"You can lift heavy loads, leap so high and feel so light not because you are stronger—the dynamometer refuted that supposition—but because the gravity is less; you will see it for yourself by using the same spring balance. We can even find out how many times less it has grown."

And he picked up the first weight to hand—it happened to be a 12-pounder—and hung it on the dynamometer.

"Look!" he continued, taking the reading. "This 12-pound weight now weighs only two pounds. That means gravity is six times less."

Then after a moment's thought he added:

"This is exactly the gravity on the surface of the Moon, owing to its small volume and small density."

"We're not on the Moon, are we?" I guffawed.

"Supposing we are," the physicist laughed, assuming a frivolous tone, "there is not much to worry about, for if such a miracle is possible, it can be repeated in reverse order which means we'll get back to where we belong."

"That's enough quibbling. But suppose we weigh something on an ordinary pair of scales? Will the diminished gravity be noticeable?"

"No, because the object being weighed will lose the same amount of weight as the weight on the other pan. The scales will balance despite the changed gravity."

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* One pood is 36 lb.—*Tr.*

** One arshin equals 28 inches.—*Tr.*

"I see!"

Nevertheless, I tried breaking a stick, hoping to find I was stronger. But I could not do it though the stick was not thick and only the day before had yielded in my hands.

"How stubborn you are! Chuck it!" said my friend. "You'd do better to think about how perturbed the world probably is now because of all the changes."

"You are right," I replied, dropping the stick. "I'd forgotten it all, forgotten about mankind with whom I, like you, passionately wish to share our thoughts."

"Something's happened to our friends. Could there have been other upheavals?"

I had opened my mouth to speak and had pulled aside the curtains (drawn to the night before to shut out the moonlight that prevented us from sleeping), but immediately recoiled. Horror of horrors! The sky was blacker than the blackest ink!

Where was the town? Where were the people?

This was some wild, inconceivable place, bathed in bright sunshine!

Perhaps we had indeed been transported to a desert planet?

These thoughts passed through my mind, I could not express them. I merely muttered incoherently.

My friend rushed across to me, presuming that I felt faint, but I pointed to the window. He looked out and was petrified with astonishment.

That we did not actually faint was because the small gravity prevented too much blood from rushing to the heart.

We looked around us.

The curtains were still drawn and we could no longer see the astonishing spectacle. Meanwhile, the normal appearance of the room and the familiar objects helped to restore our peace of mind.

Standing close together, and still a little scared, we first lifted a corner of the curtain and then drew it

completely aside. Finally we decided to step outside and observe the funereal sky and our surroundings.

Though our minds were filled with thoughts of the walk we intended to take, there were one or two things we particularly noticed. Thus, when we walked about the large, high-ceilinged rooms, we had to use our crude muscles with some caution, otherwise our feet just slid over the floor; there was no danger, however, of falling as might happen on damp snow or ice. But our bodies bobbed about very much. When we wanted to move rapidly, we had first to lean perceptibly forward like a horse when starting to pull a heavy cart. It only appeared to be like that, because actually every movement we made was extremely light. How boring it was to descend a staircase, step by step! How slow to move at a walking pace! Soon we abandoned all these procedures, so suitable on the Earth but so ridiculous here. We learned to move by leaps and bounds; we took ten or more steps at a bound up or down the staircase like the most harum-scarum schoolboys; sometimes we jumped the whole flight or leapt through the window. In short, by force of circumstances we were transformed into jumping animals, like grasshoppers and frogs.

So, after rushing all over the house, we jumped out and ran in leaps and bounds towards the nearest mountain.

The Sun was dazzlingly bright and seemed almost blue. Shielding our eyes with our hands to protect them against the glare of the Sun and the brightness of our surroundings, we could see the stars and planets which were also, for the most part, tinted blue. Neither stars nor planets twinkled, which made them like silver-capped nails studding the black firmament.

Ah! there was the moon, in its last quarter! We could not help being amazed, since its diameter seemed three or four times larger than that of our old familiar Moon. And it shone more brightly than it does in daylight on the Earth, when it appears as a small, white cloud. Silence

reigned. The skies were clear and cloudless. We could see no plants, no animals. A desert with a black monotonous firmament and blue cadaverous Sun overhead. No lakes, no rivers, not a drop of water! If only the horizon were lighter—that would indicate the presence of vapour. Alas, it was as black as the zenith!

There was nothing of the wind that rustles the grass and sways the tree tops on the Earth. No chirping of grasshoppers. No birds, no brightly coloured butterflies! Nothing but endless mountains, forbidding, high mountains, on whose peaks no snow sparkled. Not a snow-flake anywhere! And there lay the valleys, plains, and table-lands, heaped high with stone and rock, black and white, large and small, and all of them jagged and shining. None were rounded or softened by waves; they had never rolled here, had never merrily, noisily, dragged at them in play, had never worked on them!

Here was an undulating, smooth area, without a single pebble. Only dark crevasses sprawled out in all directions like snakes. This was a solid floor of rock with no soft humus, no sand, no clay.

A gloomy spectacle! Even the mountains stood bare in shameless nakedness. They had no flimsy veil, none of the transparent, grey-blue mist which envelopes mountains and remote objects on the Earth. Nothing but severe, strikingly well-defined landscapes! And the shadows! How deep they were! What sharp changes from darkness to light! There was nothing of the so familiar colour modulations that only an atmosphere can produce. Even the Sahara desert would seem a paradise compared with what we were seeing here. We would hardly have minded the scorpions and locusts, the white-hot sands tossed up by the dry wind, not to mention the rarely encountered sparse vegetation and groves of date palms. But we had to think of returning. The ground was cold and our legs and feet felt frozen, yet the Sun was baking hot. We had the unpleasant feeling of coldness which one gets when one is

freezing cold yet trying to get warm in front of a blazing fire-place; the room seems too cold to get warm in, and although a pleasant feeling of warmth covers the outer skin, nothing seems able to prevent one from shivering.

We warmed ourselves on the way back by skipping with chamois-like ease over large rocky boulders. They were rocks of granite, porphyrite, syenite, rock crystal, various quartzes and silica, transparent and opaque, and all of volcanic origin. Incidentally, we observed also traces of volcanic activity.

At last we were back home!

Inside we felt fine: at least there was an even temperature. So we felt inclined to try out a number of new experiments and to discuss everything we had seen. Clearly we were on another planet, which had neither air nor any other atmosphere.

If there were gas, the stars would twinkle; if there were air, the sky would be blue and the distant mountains veiled in mist. But how were we able to breathe and hear each other? That was something we could not understand. From a mass of phenomena it was evident that there was neither air nor gas of any kind: we could not light a cigar, and we rashly used up innumerable matches trying to do so. We were able to compress a closed, impermeable rubber bag without the slightest effort, which we could not have done if there had been gas inside. Scientists indicate that there is no gas on the Moon, too.

"Perhaps we are on the Moon, after all?"

"Have you noticed that from here the Sun seems no bigger and no smaller than from the Earth? This would be so only from the Earth and from its satellite, as these celestial bodies are almost equidistant from the Sun. From other planets it should seem either larger or smaller. Thus, from Jupiter we would see the Sun at a fifth of the present angle, and from Mars, at two-thirds the angle. From Venus, on the contrary, the angle would be one and a half times greater. On Venus the Sun burns twice as fiercely,

whereas Mars feels only half the warmth. And there is the same difference from the Earth's two closest planets! But on Jupiter, for example, the warmth received from the Sun is only one twenty-fifth of what the Earth gets. We do not see that sort of thing here, though we well could, if it existed, because we have enough of protractors and other measuring instruments."

"Yes, we are on the Moon. Everything points to it!"

"It is even borne out by the size of the cloud-like moon we saw, which is evidently the planet we departed from not of our own accord. What a pity we cannot now discern its spots, its profile, and determine our location once and for all. Let us wait till nightfall."

"So you say," I remarked to my friend, "that the Earth and the Moon are the same distance away from the Sun? But in my opinion, the difference is all the same fairly large, 360,000 versts*."

"But I said almost, since 360,000 versts are only 1/400th part of the total distance to the Sun," the physicist objected, "and 1/400th can be ignored."

II

How tired I was, not so much physically as morally! I had an irrepressible desire to sleep. What would my watch tell me? We had risen at 6 a.m. and now it was 5 p.m. Eleven hours had passed, yet, judging by the shadows, the Sun had scarcely moved. The shadow from the steep hill yonder had barely reached the house and it was in the same position now; the shadow cast by the weather-vane still lay on the same boulder.

More proof that we were on the Moon!

Indeed, its axial rotation was as low as that. Here, the day lasted for as long as about 15 of our 24-hour days, or 360 hours. And the night was just as long. Not very

* One verst is 3,500 feet.—*Tr.*

convenient. The Sun prevented us from sleeping. I remember experiencing the same thing when I spent a few summer weeks in arctic lands. The Sun never sank below the horizon and I grew sick and tired of it! However, there was a great difference between my experiences then and now. Here the Sun was moving slowly but in the same way. There it moved quickly, describing a circle once every 24 hours just above the horizon.

But in both places there was the same remedy: to close the shutters.

But was my watch right? Why did my watch not tally with the pendulum clock on the wall? My watch indicated five o'clock, and the clock on the wall—only ten a. m. Which was right? Why was the pendulum swinging so lazily?

Quite obviously the clock on the wall was slow!

My watch, on the other hand, could not be wrong as its pendulum is not swung by gravity but by the resilience of a steel spring, which is the same on the Earth as on the Moon.

I could check this by feeling my pulse. It used to beat 70 times a minute. Now it beats 75 times. A little more than usual, perhaps, but that may be due to the nervous excitement of finding myself in such unusual circumstances and to all the strong new impressions.

There was still another way of checking the time. At night we would be able to see the Earth turning on its axis once every 24 hours. That is the best clock, an infallible one!

Though we could hardly keep awake, my physicist friend could not resist the temptation to put the clock right. I watched him remove the long pendulum, accurately measure it and shorten it to a sixth of its previous length. But even the shortened pendulum behaved staidly, though not quite like the longer one. After the metamorphosis, the clock ticked off the hours in harmony with my watch.

At last we went to bed and covered ourselves with the light blankets, which here seemed almost ethereally light.

We hardly made use of pillows or mattresses at all. One could sleep soundly on boards here.

I could not rid myself of the idea that I was going to bed too early. The Sun! The time! They were frozen stiff into stillness like the whole nature of the Moon!

My friend was no longer conversing with me; I too dozed off.

We woke up in good spirits. We felt cheerful, but famished. Until now, the excitement had deprived us of our customary appetites.

How thirsty I was! I removed the stopper from my water-bottle but what did I find? The water seemed to be boiling! Slowly and gently boiling. Cautiously I touched the water-bottle in case it was too hot. But no, the water was only warm and most unpalatable!

"My dear friend, what have you to say about this?"

"We are in an absolute vacuum, which is why the water is boiling, not being subject to atmospheric pressure. Let it boil a while. Don't put the stopper back. In a vacuum boiling water gradually freezes. But we shall not let it freeze. That is enough! Pour some water into a glass and stopper the bottle, otherwise too much will boil out."

How slowly liquid pours out here on the Moon!

The water in the bottle became still, but in the glass it continued its lifeless agitation, which with time became weaker.

The water left in the glass turned to ice. Then the ice evaporated and grew smaller in size.

How would we be dining now?

It was easy enough to eat bread and other more or less solid foods, though they rapidly dried up in our by no means air-tight box. The bread had turned to stone, the fruit had shrivelled and become pretty hard. Of course the skin and peel had helped to retain some moisture.

"This habit we have of eating hot dishes! What are we going to do? We can't start a fire here: no wood, no coal, even no matches will burn here!"

"What about making the Sun do the job? After all people cook eggs in the hot sand of the Sahara desert!"

We adapted our pots, saucepans and other utensils, so that the lids fitted tightly. Then, filling them all according to the rules of culinary art, we set them out in the sunshine. Then we collected all the mirrors from the house and set them up so that the sunlight was concentrated onto the pots and pans.

In less than an hour we were enjoying well-steamed, well-baked food.

But why talk about it? Have you heard of Mouchauld?* We left his improved system of solar cooking far behind! Call it boasting or bragging, if you like. Perhaps our presumption should be attributed to our ravenous appetites, due to which any foul food would have seemed perfection.

There was one nasty thing about it, however: we had to hurry. I must confess that we more than once choked and spluttered over our food. And no wonder, for the soup boiled and cooled not only in our plates but even in the throat, oesophagus, and stomach. If we did not look alive about it, we found ourselves swallowing a lump of ice instead of soup.

It was surprising that our stomachs remained unharmed! The pressure exerted by the vapour greatly distended them.

At any rate our appetites were satisfied and we felt at peace with ourselves. We did not understand how we were living without air, and how we, our house, our garden and orchard, our stores of food and drink in the cellars and barns had been transported from the Earth to the Moon. We even had our doubts. We began to think perhaps we were asleep and dreaming or that we had fallen victim to some diabolical hallucination? But for all that, we grew accustomed to our situation and treated it with mixed feelings of curiosity and indifference. The inexpli-

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* Mouchauld chose astronomical subjects for the science fiction stories he wrote in the 1890's.—*Ed.*

cable no longer astonished us and the thought never entered our minds that we might die of starvation, alone and miserable.

As the story of our adventures unfolds, you will discover why we were so incredibly optimistic.

An after-dinner constitutional would not be amiss, I thought.

I persuaded my friend to accompany me.

We stood in a big courtyard, with a climbing pole standing erect in the middle, and a fence and outhouses all around.

But what was the reason for this boulder? One could easily fall over it. In the yard the ground was of ordinary, soft earth. Let's chuck it out, over the fence! Pick it up boldly! Don't let its size perturb you! With our united efforts, we lifted the 60-pood boulder and tumbled it over the fence. We heard it drop with a thud on the Moon's rocky surface. We heard the thud not through the air, but from the ground. The impact produced a concussion on the ground and then on our bodies and the bones in our ears. In this manner we could often hear the blows we struck.

"Perhaps this was the way we heard one another?"

"Hardly so! The sound would not be heard as it is heard in the air."

The ease with which we moved gave us a strong desire to climb and jump.

Sweet childhood days! I remembered climbing onto roofs and tree tops, imitating the cats and birds. How wonderful it had been!

And the competitions for the high jump over ropes, the long jump over ditches! The races for a prize! These were my passion!

Should I recall old times? I was not very strong, especially my arms. I could jump and run pretty well, but climbed ropes and poles with difficulty.

I had always longed to be physically strong! To pay back my enemies, to reward my friends! The child and the

savage are one. These dreams of being strong were now ridiculous. My eager childhood longings had now been fulfilled. Because of the Moon's insignificant gravity I seemed now to be six times as strong as before.

Moreover, the weight of my own body now meant nothing to me, which fact increased the effect of being strong. What was a fence to me now? No more than the threshold or a stool on the Earth over which I could step with ease. And, as if to test this thought in action, we soared up and without a running start leapt over the fence. Then we jumped and even bounded over the shed, but for this we had to have a running start. How pleasant it was to be racing about! We could hardly feel our feet. Let's run a race. Off we go!

Whenever our feet struck the ground we leapt several yards, especially horizontally. Whoa, there! In one minute we had raced round the entire yard. Five hundred sazhens* —the speed of a race horse.**

We took some measurements. At an easy gallop we rose some four arshins upwards and in length we leapt five sazhens or more, depending on the speed at which we ran.

"Now for some gymnastics!"

Making hardly any effort, and simply to amuse ourselves, we climbed the rope, using only the left hand.

It was terrifying! After all, it was a four sazhens drop! We still felt we were on our own clumsy planet. Our heads went round and round.

My heart was in my mouth, but I decided to jump first. Here I go. Ouch! I knocked my heels!

I should have warned my friend, but instead I slyly egged him on. Raising my head I shouted:

"Come on, jump! You won't hurt yourself!"

"I don't need you to persuade me. I know perfectly well that to jump from this height is the same as jumping from

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* One sazhen equals 2.3 metres.—*Tr.*

** The speed is slightly exaggerated.—*Ed.*

a height of two arshins on the Earth. I know I'll bash my heels a bit!"

My friend jumped. It was a slowish process, particularly at first, and took him about five seconds.

Time enough to think of many things.

"Well, physicist?"

"My heart's beating fast, but that is all."

"Now for the orchard, to climb the trees and race along the paths!"

"Why haven't the leaves shrivelled?"

The verdure is fresh and will shield us from the Sun. Tall lime-trees and birches! We leapt and climbed among the thin branches like squirrels, and they did not break under our weight. No wonder, for here we are no heavier than a couple of fat turkeys!

We flitted over the bushes and among the trees, moving as though we were flying. What a merry time we had! How easy we found it to keep our balance ! We swayed unsteadily on a branch, about to fall, but the inclination to fall was so slight and the deviation from equilibrium proceeded so slowly, that we had only to shift the leg or arm slightly, to regain balance.

Now for the wide, open spaces! The big courtyard and orchard seemed like a cage. At first we raced over the level ground. On our way we encountered shallow ditches some ten sazhens across.

We took them in our stride, fleeting over like birds. We came to a hillside. At first we went up a gentle slope but later the going became steeper and steeper. So steep, indeed, it was that I felt sure I would get out of breath.

But there was no reason to fear. We took the ascent easily in long and rapid strides. It was a high hill and we felt tired on the Moon with its low gravity. We sat down to rest. Why was it so soft here? Could the rocks have softened?

I picked up a large stone and struck it against another. Sparks flew.

After resting we turned back.

"How far are we from home?"

"Not very far now, perhaps 200 sazhens."

"Do you think you could throw a stone that far?"

"I don't know, but I can try!"

We each picked up a small piece of rock. Who would throw it farthest?

Mine flew right over the house. It was just as well. As I watched its flight I greatly feared it might smash a window.

"Where did yours go? Farther still, think!"

Shooting was very interesting here. Bullets and cannon-balls should fly horizontally and vertically for hundreds of versts.

"But will gunpowder do its job here?"

"In a vacuum the force of explosives is even greater than in the air, as the latter only hampers the expansion of gases. As for oxygen they don't need it, because they themselves contain as much as they need."

III

We reached home.

"I shall sprinkle some gunpowder on the window-sill in the sunshine," I said. "Now focus your burning glass on it. You saw the flash and the explosion, though it was noiseless. And there was the familiar smell, only it vanished instantaneously.

"You can fire a rifle, only don't forget to put the percussion cap on. The burning glass and the Sun will take the place of the trigger."

"Let's aim the rifle vertically, in order to retrieve the bullet afterwards close by."

There was a flash, a slight pop and the ground shook slightly.

"Where's the wad?" I exclaimed. "It ought to be close by, though it won't be smoking!"

"The wad went up with the bullet and will most likely remain with it. Back on the Earth it is only the atmosphere that prevents it from winging after the lead bullet. Here a feather will fall or fly up as headlong as a stone. Suppose you pluck a feather from your pillow while I take a little iron ball. You'll find you can throw your feather and hit something, even far away, just as easily as I can with my little ball. I can throw the ball 200 sazhens; you can throw your feather just as far. True, you will not kill anyone with it and you will not even feel that you have thrown it. So let us throw our projectiles with all our might—I think we are about the same in that respect—at one and the same target—that lump of red granite, for instance."

We watched the feather slightly outfly the iron ball, as if carried away by a strong whirlwind.

"But what can have happened? It is already three minutes since we fired the shot, and still there's no bullet!" I exclaimed.

"Wait a couple of minutes, it's sure to come down," replied the physicist.

And indeed, roughly in the time specified we felt the ground tremble slightly and saw the wad bobbing about near by.

"But where is the bullet? The scrap of tow could not have caused the ground to tremble?" I asked in astonishment.

"Most likely, from the impact the bullet heated up to melting point and the splashes flew off in different directions."

After searching around we indeed found some tiny pellets—evidently particles of the vanished bullet.

"The bullet certainly flew quite a time! How high should it have gone?" I asked.

"Up to some 70 versts—all because of the small gravitational pull and the absence of atmospheric resistance."

* * *

We were tired mentally and physically and needed rest. The Moon is all very well in its way, but all the leaping about had made itself felt. As the flights were prolonged we did not always fall on our feet and so we sometimes hurt ourselves. In the four to six seconds we spent in flight we not only had a bird's-eye view of the vicinity, but could also move our arms and legs. But we never seemed able to somersault in space. Later we learned to control our bodies and even do as much as three somersaults in space. This is an interesting experience and it is interesting to watch others doing it. I spent a long time observing the movements of my physicist friend; he performed many experiments off the ground and without any support. To describe them I would have to write a book.

* * *

We slept for 8 hours.

It was getting warmer. The Sun had risen higher and was not beating down so fiercely. Now it shone on a smaller surface of the body, but the ground had warmed up and no longer gave off coldness. In general, both the Sun and the soil were warm, almost hot.

It was time, however, to take precautions, as we clearly realised that we would become burnt up before noon.

What were we to do?

We proposed different plans.

"We could spend a few days in the cellar, but there's no guaranteeing that towards evening, that is, in about 250 hours from now, it will not be like a furnace there, because the cellar is not deep enough. Then we shall also long for comfort and be sick and tired of remaining in a confined space."

True, it is easier to suffer boredom and inconvenience than to be baked alive.

But would it not be better to choose one of the deeper crevasses? We could climb down and spend the rest of the day and part of the night in pleasant coolness.

That would be much more amusing and romantic. What a cellar, after all?

Necessity compels people to hide in the queerest of places!

So we chose a crevasse, the idea being that the more fiercely the Sun beat down, the lower we would descend. Incidentally a few sazhens will be quite deep enough.

We took along sunshades and provisions in tightly closed boxes and barrels. We threw fur overcoats over our shoulders; they would come in useful whether it was too hot or too cold. Moreover, here they were not much of a burden.

Several hours passed, during which we ate, rested and talked of lunar gymnastics and of the wonderful miracles circus acrobats from our Earth could perform here.

We could tarry no longer. It was infernally hot, at least outside. In sunny places the rocky ground was so hot that we had to tie thick wooden boards to the soles of our boots.

In our haste we dropped some of our glass and chinaware but nothing broke, so feeble was the gravitational pull.

I almost forgot to tell of the fate that befell our horse, which, as chance would have it, was also with us. When we wanted to harness it to a cart, the unfortunate beast somehow broke loose, galloped off faster than the wind, tumbling and bruising itself and then, not understanding the force of inertia, and failing to avoid a huge boulder in its path, dashed itself to pieces. Its flesh and blood first froze and then dried up.

Then there were the flies. They could not fly at all, but merely jumped up and down.

* * *

And so, taking with us all we needed, making a tremendous load on our shoulders, which highly amused us as all of it seemed hollow and fragile, and having barred doors,

windows and shutters so that the house would not get too hot and damaged from the high temperature, we set off in search of a suitable crevasse or cave.

Meanwhile we marvelled at the sharp fluctuations in temperature. Places that had been long in the sunshine were as hot as a fiery furnace. We tried to get past them as quickly as possible and then to cool off and rest in the shade of a boulder or a cliff. And we cooled off so thoroughly that had we tarried any longer our fur coats would have come in for some use. But even these spots were not so dependable. We realised that the Sun would have to move round and shine on what had previously been in the shade and cold. So we looked for a crevasse on which the Sun would not shine for any length of time, and would not therefore make the rock very hot.

We found a crevasse with almost overhanging cliffs, only the very tops of which we could see. The crevasse itself was dark and seemed bottomless. We walked round it and found a gentle slope, which seemed to descend straight into Hades itself. We took a few steps without mishap. But then it grew so dark that we could see no further than our noses, and it seemed too horrible and risky to proceed. Happily we remembered the electric lamp; candles and torches were not possible here. The beam of light flashed before us, revealing a crevasse some 20 sazhens deep; the slope of the land made the descent quite possible.

So much for the bottomless gorge! Hades, indeed! We were most sadly disillusioned.

First of all, the darkness was because the place lay in shadow, the crevasse was narrow and deep and the light reflected from the sunlit environment and tall mountains could not penetrate it to these depths. Secondly, it was dark because there was no atmosphere to reflect light to it, whereas the atmosphere on the Earth sends diffused light down to the deepest of wells which are therefore not so dark as on the Moon.

As we descended, now and then clutching at the walls, the temperature dropped, though not below 15°C. Evidently this was the mean temperature of the latitude we were in. We chose a convenient, level spot, spread out our fur coats and made ourselves comfortable.

But what was this? Had night fallen? Shielding our eyes from the beam of the lamp, we peered at the slit of black, star-spangled sky overhead.

Our timepiece showed that little time had passed and we knew the Sun could not have set so suddenly.

Confound it! An awkward movement has shattered the lamp, though its carbon filament continues to glow and even more brightly. Back on the Earth it would have gone out at once, burning itself out in the air.

Out of curiosity I touched it. It snapped, and everything was plunged in darkness. We could not see one another. Only high above us we could just discern the edges of the crevasse, and the long narrow strip of the dark firmament seemed studded with still more stars.

We could not believe that it was broad daylight up there. I became impatient; with some effort I dug out a spare bulb, switched on the lamp again and began the ascent. It grew brighter and warmer. The light blinded me, and my lamp seemed to have gone out.

It was indeed daylight; both the Sun and the shadow were there as before.

How hot it was! I hurried down again.

IV

Idle, we slept like logs. Our refuge kept cool.

Now and again we climbed out to find a shady place and observe in their stately motion the Sun, stars, planets and our big moon, which compared to your miserable Moon was as large as an apple compared to a cherry.

The Sun moved almost in step with the stars, barely

perceptibly falling behind them, just as when observing it from the Earth.

Meanwhile, the moon hung quite still and was invisible from our crevasse, which we greatly regretted, as from the darkness we might have observed it just as well as at night-time, for which we had to wait a long time. It was unfortunate that we had not chosen some crevasse from which the moon would have been visible. But it was now too late.

It was almost midday. The shadows were no longer growing shorter and the moon had dwindled a slender crescent, growing paler and paler as the Sun drew close.

The moon was as large as an apple, the Sun the size of a cherry. Would the cherry glide behind the apple? Would there be an eclipse of the Sun?

On the Moon this is a frequent and magnificent phenomenon; on the Earth it is rare and insignificant. There the umbra, the size of a pinhead (it is sometimes several versts long—but what is that if not a pinhead compared with the size of the Earth?), pencils a strip across the planet, and, in favourable circumstances, passes from town to town, spending a few minutes in each. But here the umbra covers either the whole Moon, or, in most cases, a considerable part of its surface, so that complete darkness lasts for several hours.

The crescent grew slenderer still, and was barely noticeable beside the Sun.

Then it completely disappeared.

We climbed out to observe the Sun through a piece of dark glass.

It seemed as though a gigantic invisible finger had flattened one side of the Sun's glowing mass.

Then only half the Sun was visible.

Finally, its last limb vanished, and everything was plunged into darkness.

A vast pall of shadow stole up and covered us.

But the feeling of being blind quickly vanished. We again saw the moon and a multitude of stars.

This was no longer a crescent moon. Now it was in the shape of a dark circle, standing out magnificent radiance of deep red light that shone most brilliantly, though slightly paler on the side where the last of the Sun had disappeared.

What we were seeing was the same sunset glow we had once gloried in on the Earth.

The entire surroundings were bathed in a blood-red glow.

Meanwhile, thousands of people on the Earth with the naked eye or through telescopes were observing a full eclipse of the Moon—and us!

The eyes of our own human race! Could they perhaps see us?

As we stood commiserating, the glowing corona assumed a more even shape and became more beautiful; it became similar in size to the crescent itself; the eclipse was at its height. Then the side opposite to that behind which the Sun had disappeared paled and grew more luminous, its brilliance increasing in intensity until it resembled a diamond set in a crimson ring.

The diamond became a segment of the Sun and the outer radiance vanished. Night changed to day, the enchantment was gone. The landscape before our eyes was as it had been before the eclipse. We conversed together animatedly about what we had just witnessed.

Earlier I mentioned that we had chosen a shady place and made observations. But you may ask: "How were you able to observe the Sun from a shady place?"

This is my answer: "Not all shady spots were cold and not all sunlit places hot. Indeed, ground temperature depends mainly on how long the Sun has been warming it. But there were areas on which the Sun began to shine just a few hours previously and which before that had been in the shade. Naturally, the temperature there could

not have been so very high. On the contrary, it would have been excessively cold. Wherever there are cliffs and steep mountains throwing shadows, there will be places which are cold, though they are sunlit, and though from them the Sun can be seen.

"True, they are not always to hand, and before they are found and arrived at, even a sunshade will not save you from being thoroughly baked."

For the sake of convenience and partly to get limbered up, we decided to take with us a fair supply of the many still cold stones lying about in our crevasse, planning to heap them out in the open and thus shield our bodies from the heat.

No sooner said than done.

We were thus always able to emerge and, squatting deep down among the pile of stones, conduct our observations.

But the stones would get hot in time!

Well, we could go back for more, there were so many of them down below, in the crevasse. With our strength increased sixfold because we were on the Moon, it was hardly likely to give out.

We did all this after the solar eclipse, which we had not expected with certainty.

Besides this, no sooner had the eclipse passed than we determined to ascertain our latitude. This was easy enough, having in view the Sun's altitude and the period of the equinox (this being evident from the recent eclipse). We found we were in latitude of 40°N, so we were not on the Moon's equator.

Thus half the day—seven Earth days from the sunrise we had not seen—had already gone by. Indeed, our timepiece showed that our sojourn on the Moon had lasted five Earth days. Consequently we had arrived on the Moon at 48 o'clock in the early morning. That was why we found the ground very cold when we awoke. There had been no time for it to warm up after being terribly cooled off by the preceding long night of 15 Earth days.

* * *

We slept and woke, and each time saw more and more new stars above. They were the self-same stars set in the same familiar pattern as those seen from the Earth. Only because of the narrowness of the deep hollow we were lying in, we could not at a glance see their vast numbers. Nor did they twinkle against their black background, and they moved twenty-eight times more slowly than the speed observed from the Earth.

Then Jupiter appeared. Its satellites could here be seen with the naked eye and we observed their eclipse.* Then Jupiter went out of sight and the Polar Star came out. Poor star! It is of no importance here. The crescent alone would never peep into our crevasse, if we sat there for a thousand years, for it is eternally immobile. Only if we move ourselves on this planet, can it be set in motion. Then it will descend, rise and set. But we shall return to this point later.

* * *

We could not sleep and sleep all the time!

And so we began to make plans.

"Tonight we shall climb out of our crevasse, but not immediately after the Sun sets when the ground is at its hottest, but several dozen hours later. We shall set off for our house and see what has happened there. Whether the Sun has been up to mischief? Then we shall make a voyage by moonlight, enjoy the sights of this moon. So far we have seen it as a milk-white cloud; at night-time we shall admire it in its full beauty, its brilliance, every aspect of it, since it revolves rapidly and shows itself in not more than 24 hours, a mere fraction of the lunar day and night together."

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* An observer on the Moon would never be able to see Jupiter's satellites, and still less eclipses of them, with naked eye.—*Ed.*

Our large moon, the Earth, has phases like the Moon we used to watch from afar with dreamy curiosity.

In our locality new moons or, rather, new earths occur at noon: the first quarter is at sunset, the full moon—at midnight, and the final quarter—at sunrise.

We are in a locality, where nights and even days are eternally moon-nights and moon-days. This is admirable but only while we exist in the hemisphere, visible from the Earth. As soon as we pass to the other hemisphere, invisible from the Earth, we shall immediately lose the light during the night. And this will be so for as long as we stay in this unfortunate, and, at the same time, so mysterious hemisphere. It is mysterious for the Earth since the Earth never sees it and that is why it intrigues scientists so very much. It is unfortunate because its inhabitants, if any, are deprived of a nocturnal luminary and a magnificent spectacle.

Indeed, are there any inhabitants on the Moon? What are they like? Are they like us? So far we had not met them. It would have been pretty difficult to do so, since we had been keeping almost in one place all the time and had occupied ourselves far more with gymnastics than with selenography. Of special interest is the unknown half, whose dark heavens at night are eternally studded with a legion of stars, most of which are telescopically minute since their tender glow is neither destroyed by multiple atmospheric refractions nor dulled by the harsh light of an immense moon.

Could there be depressions there, in which gases, liquids and a lunar population could accumulate? These formed the subject of our conversations, as we waited for the sunset and the night. Impatiently we waited for nightfall. It was not really boring, for in addition we called to mind the experiments with lamp oil, which my physicist friend had mentioned earlier.

The fact is, we had succeeded in getting drops of huge dimensions. For instance, when drops of oil fell from a

horizontal plane they reached the size of an apple. Drops from a sharpened tip were much smaller. Oil poured through a hole, flowed at a speed that was two-fifths of what it would be on the Earth, the conditions being the same. Capillary attraction* on the Moon was six times greater than on the Earth. Thus, round the sides of the container the oil rose above the general level with an intensity six times greater than that on the Earth.

In a small wine glass, the oil assumed a compressed, almost spherical, shape.

Nor did we forget our sinful bellies. Every 6-10 hours we fortified ourselves with food and drink.

We had with us a samovar with a lid screwed on tightly and we often sipped a brew of the Chinese herb.

Of course we could not get the samovar going in the ordinary way, as air is required to make coal and wood chips burn. We merely stood it out in the Sun, packed round with a pile of hot stones. The water soon began to simmer, but did not boil. Hot water would spurt from the open tap, under the pressure of the inside steam, which was not offset by outside atmospheric pressure.

Taking tea in this way was not particularly pleasant, because of the possibility of scalding ourselves, for the water spurted all over the place like exploding gunpowder.

So we put the tea into the samovar, then let it first heat up thoroughly, then shifted the hot stones away and waited for it to cool off. Only then did we drink the ready-brewed tea without scalding our lips. However, even this tepid tea spurted out fizzing into our glasses and seemed like soda water in our mouths.

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* Capillary attraction is the adhesion of liquids by virtue of which kerosene, for instance, rises up a wick, or sap flows towards the leaves. It is a complex phenomenon which occurs in a multitude of forms.

V

Soon the Sun would be setting.

We watch the Sun touch a mountain peak. On the Earth we would have done this with the naked eye. Here it was impossible, because here there was no atmosphere and no water vapour, and consequently there had been nothing to detract from the Sun's bluish tinge, its heat, or its brilliance. We were able only for a brief instant to glance at it without dark-tinted glass. It was not at all like the rosy, soft light of the Sun when it is rising or setting on the Earth!

Slowly the Sun sank lower and lower. Half an hour had passed since it first touched the horizon, yet half of it had not disappeared.

In St. Petersburg or Moscow the Sun sets in three to five minutes. In tropical climes the sunset lasts for about two minutes. Only at the poles does it take several hours to set.

Finally, the last segment of the Sun, seeming like a bright star, died out behind the hills.

And no sunset glow at all!

Instead we saw all around us the multitude of mountain peaks and other hilly areas glowing in a rather bright reflected light.

This light was quite enough to prevent complete darkness for several hours, even when there was no moon.

One remote peak shone like a beacon for 30 hours.

Finally this, too, went dim.

Now only the moon and the stars were shining down, but the light from the stars was very faint.

Immediately following the sunset and even for some time afterwards, the reflected sunlight was more powerful than the moonlight.

But when the last mountain beacon had faded, our nocturnal luminary reigned in full grandeur over the Moon.

We turned and looked at it.

Its surface was 15 times greater than that of the Earth's Moon, which, as already mentioned, was the size of a cherry compared with an apple.

The light it emitted was 50 to 60 times more powerful than that of the Moon, we had been accustomed to.

It was possible to read without straining the eyes, it did not seem to be night at all—rather a fantastic kind of day.

Its glow prevented us from seeing either the zodiacal light or the smaller stars, without using special screens.

What a spectacle! Greetings, Earth! Our hearts beat with a bitter-sweet longing, our minds were filled with recollections!

How precious and mysterious now was this once cursed and banal Earth! We saw it as a picture behind a pale blue glass. The glass was the ethereal ocean of the Earth!

We saw Africa and part of Asia, the Sahara desert, the Gobi desert and Arabia! Lands, where it never rains and the skies are always blue! They are unblemished, always open to the eye of the selenite. Only as the planet turns on its axis does it carry these deserts away.

The white amorphous tufts and strips are clouds.

The ground seemed to be a muddy-yellow or muddy-green.

The seas and oceans were dark, but of different shades which most likely depended on how turbulent or still they were. Where the sea was whitish white horses rode the billows, perhaps. In places the waters were obscured by clouds, not all snow-white, though few were greyish. They were evidently covered by upper light strata composed of an icy, crystallic dust.

The two diametrically opposite sides of the planet shone particularly brightly due to the polar ice caps.

The white cap at the north was purer and larger than that in the south.

Had the clouds been motionless it would have been difficult to distinguish them from the snow. Incidentally

the snows for the most part lie deeper down in the ocean of air, so that the blue colouring that conceals them is a shade darker than that above the clouds.

There was a sprinkling of snow scattered over all parts of the planet, even along its equator. These were the mountain peaks, which were so high, that even in the tropics the snow caps did not melt.

There were the gleaming Alps!

And there the Caucasian Mountains!

And over there the Himalayas!

The patches of snow were more constant than the clouds, but even they changed, disappearing and reappearing with the different seasons.

If we had only had a telescope, we would have been able to detect all the details. It would have been a lovely sight!

The planet was in its first quarter. Illuminated by the feeble moonlight, the Earth's darker half was barely discernible, being much darker than the darker (ashen) part of the Moon that is visible from the Earth.

We felt hungry. But before descending into the crevasse we decided to find out whether the ground was still very hot. We stepped down from our rocky platform—by now we had renewed it several times—and plunged into what seemed like an incredibly hot bathhouse. The heat quickly penetrated the soles of our boots, and we beat a hasty retreat. The ground would not cool for some time*.

We dined in the crevasse, the edges of which had already ceased to shine; from there a mighty host of stars was visible.

Every two or three hours we climbed out to observe our moon—the Earth.

We could have taken it all in at a glance but for the clouds covering our planet. To some parts the clouds

* As the Moon has no atmosphere, its surface cools extremely rapidly.—*Ed.*

clung obstinately, trying our patience, even though we still hoped that we would see them. And when fine weather set in, we did observe them.

* * *

We spent five days under cover in the depths of the Moon, emerging only to spend brief intervals in the immediate vicinity.

The ground cooled and after five Earth days, or towards lunar midnight, it was so cool that we resolved to embark on a journey over the hills and dales of the Moon. Actually, we had not as yet visited any low-lying place.

The accepted name for these vast, darkish low-lying lunar expanses is the maria or seas, which is really quite wrong because no water has ever been found there. Would we be able to discover in these "seas" and still lower places any traces of Neptunian activity—traces of the water, air and organic life, which some scientists consider long vanished from the Moon? It has been suggested that at one time all this existed on the Moon, and perhaps still does in some of its crevasses and abysses; that there had been both water and air but that with the passage of time, it had all soaked into and been absorbed by the soil, and had formed chemical compounds with it; that there had once been organisms—vegetation of a simple order, and shell-fish, because where there is water and air, there will be mould, and mould is an original form of organic life, at least of the lowest order.

As for my friend, the psysicist, he thought, with good reason, that there had never been any life, water or air on the Moon. If there had been water and air, their temperatures would have been so high that any organic life would have been impossible.

My reader will forgive me for giving here the personal view of my friend, which has no proof to support it.

At any rate, when our round-the-Moon voyage is over, we shall know who was right.

And so, shouldering our loads, which had grown much lighter due to the vast quantities of food and drink consumed, we parted with our hospitable crevasse and, taking our bearings by the immobile moon suspended in the black firmament above, set off for our house, which we shortly discovered.

The wooden shutters and other wooden parts of the houses and sheds had become rotten and charred on top, due to the prolonged action of the Sun's rays. In the courtyard we found broken bits of a water cask, which had exploded from the pressure of the steam. We had stupidly bunged up the cask and left it out in the baking Sun. There were, of course, no traces of water, it having completely evaporated. By the porch we found some slivers of glass. This was from the lantern, the frame of which was of an easily fusible metal. Quite understandably, it had melted and the glass had fallen out. Inside the house, we found less damage: its thick brick walls had given good protection. In the cellar everything was intact.

Taking from the cellar everything required to prevent us dying of starvation and thirst, we set forth on a long journey to the lunar pole and to that other, mysterious hemisphere which no man had ever seen before.

"Would it not be advisable for us to trail the Sun westwards, at the same time deviating a little towards one of the poles?" my physicist friend suggested. "We would kill two birds with one stone, the first being that we would reach the pole and the reverse hemisphere, and the second, that we would avoid excessive cold, since if we keep abreast of the Sun, we shall travel through places warmed by the Sun for a definite period of time, that is, through places having a constant temperature. We may even change the temperature at will, to suit our requirements: by overtaking the Sun we shall raise it; by lagging behind we shall cause it to drop. This will be particularly advantageous considering that we are approaching the pole, where the mean temperature is low!"

"Really? Is that possible?" was my response to the physicist's odd theories.

"Quite possible!" he replied. "Just bear in mind how easy it is to run on the Moon and how slow the Sun's apparent motion is. The greatest lunar circle is ten thousand versts long. To keep up with the Sun, this distance has to be covered in 30 days or seven hundred hours, in terrestrial terms. Consequently, we must go at fourteen and a half versts an hour."

"Fourteen versts an hour on the Moon!" I exclaimed. "That's a mere trifle."

"Well, there you are!"

"We'll do twice that with the greatest of ease," I continued, recollecting our gymnastics. "Then we shall be able to sleep twelve hours out of the twenty-four."

"The parallels are different," the physicist explained. "The nearer to the pole, the shorter they will be, and since we intend to cross the pole, we shall keep up with the Sun even by gradually slowing our pace. But the polar cold will prevent us. As we approach the pole, we must get closer to the Sun, if we are not to freeze to death. In other words, we must travel over places which, though near the pole, will have been longest in the Sun. At the pole the Sun does not rise high above the horizon and so it heats the ground much less intensively, and even at sunset it is only just warm.

"The nearer we draw to the pole, the closer we must be to where the Sun sets in order to be in the most constant temperature."

"So, Westward Ho!"

We slid along like shadows, like ghosts, our feet noiselessly touching the pleasantly warm ground. By now the moon was almost completely spherical and therefore extremely bright, presenting an enchanting picture behind a pale-blue glass which seemed to thicken towards the outer edges where the shade of blue was darker. At the

very edges we could not distinguish the land, the water or the shape of the clouds.

First we saw the hemisphere, a wealth of dry land. Twelve hours later, we saw just the opposite: a hemisphere with an abundance of water, almost the size of the Pacific. It poorly reflected the rays of the Sun, consequently had it not been for the brightly lit clouds and ice, the moon would not have been as bright as it then appeared.

We climbed ascending slopes easily, and ran down again with still greater ease. From time to time we dived into the shade, from which more stars were visible. So far we had encountered only small hills. But even the tallest mountains were no obstacle, because on the Moon the temperature does not change with the altitude. Mountain peaks are just as warm and free of snow as the valleys. Undulating stretches, cliffs and abysses are not formidable on the Moon. We leapt over uneven ground and crevasses ten to fifteen sazhens wide. When they were very wide and beyond our powers, we either by-passed them or climbed their steep cliffs and terraces with the help of a line, sharp hook-handled sticks and spiked boots.

You will understand why no stout ropes were required when you remember how little we weighed.

"Why not head for the equator? We haven't been there yet, have we?" I ventured to remark.

"There is nothing to prevent us," my friend acquiesced.

We changed our course at once.

We were running too fast, and so the ground grew warmer and warmer. Finally, we found it impossible to run because of the heat; we had reached places which had been more fiercely heated by the Sun.

"What will happen," I asked, "if, despite the heat, we run on at the same speed and in the same direction—westward?"

"Running at this speed, in seven Earth days, we would first see Sun-lit mountain peaks and then the Sun itself rising in the west."

"Would the Sun really rise where it usually sets?" I said, doubtfully.

"Yes, it would, and if we were legendary salamanders, insured against fire, we would actually be able to convince ourselves of the fact."

"Would that mean that the Sun would appear and again vanish, or that it would rise in the usual way?"

"As long as we run along the equator, say, faster than fourteen and a half versts an hour, the Sun will be moving from west to east where it will set. But as soon as we stop, it will at once move in the usual way and, forcibly elevated in the West, will again sink below the horizon."

"And supposing we keep going steady at fourteen and a half versts an hour, no more and no less, what will happen then?" I persisted.

"Then the Sun will stand still in the skies, as in the days of Joshua of Jericho, and there will be no end either to day or night."

"Could this hocus-pocus be done on the Earth?" I interjected.

"Yes, as long as you are able to run, ride or fly at a speed of over 1,540 versts an hour."

"Fifteen times faster than a tornado or hurricane! I won't undertake to do that ... oh! I forgot ... I mean, I wouldn't undertake to do it!"

"Of course not! What can be done here with ease is quite unconceivable on that Earth," said the physicist, pointing at the moon.

So we debated, seated on the rocks. As I said, it was impossible to continue running because of the heat.

Tired out, we soon fell asleep.

The cold awoke us. Agilely jumping to our feet, and leaping forward, five arshins to the bound, we raced onwards to the west, veering towards the equator.

You will remember that we determined the latitude of our house as being 40°; so it was still a fair distance to the equator. But do not imagine that a degree of latitude

on the Moon is as long as on the Earth; remember that the size of the Moon compared to the Earth is like a cherry to an apple; hence a degree of lunar latitude is not more than 30 versts, while a degree of terrestrial latitude is 104 versts.

By the way, we realised that we were nearing the equator from the fact that the temperature in the deep crevasses, representing the mean temperature, was gradually rising; but after reaching 50°R it stopped there. Then it even began to drop, indicating that we had crossed into the other hemisphere.

We determined our position more accurately astronomically.

But before we crossed the equator, we had encountered many mountains and dry "seas".

People on the Earth are very familiar with the shape of lunar mountains. They are mostly rounded with a crater in the centre.

But the central crater is not always empty, not always of the most recent origin. Sometimes, in the middle, there is another big mountain again with an inside depression indicating a crater of more recent origin. It is very seldom active and has reddish lava inside at the very bottom.

Were these perhaps the volcanoes that had at one time ejected the rocks we found pretty frequently? Otherwise I could not understand how they came to be there.

Out of curiosity we deliberately ran round the very top of the volcanoes and, glancing into the craters, twice watched the glowing, undulating waves of lava below.

On one occasion, to one side of us we spotted above a mountain peak a huge tall pillar of light, probably consisting of a large quantity of white-hot luminescent rocks. Our light feet felt the tremor as they struck the ground.

Whether because of the shortage of oxygen on the Moon or for some other reasons, we only found unoxidised metals and minerals, mostly aluminium.

Contrary to the convictions of my friend, the low-lying,

level areas and the dry "seas" in other places were covered with obvious, though meagre, traces of Neptunian activity. We liked these lowlands where our heels threw up dust; but as we ran so quickly, the dust remained behind and settled at once as there was no wind to rake it up and blow it into our eyes and noses. We liked them because after bruising our heels on the rocks, they felt like soft carpets or grassland. This alluvial layer did not impede our progress for it was not more than a few inches thick.

The physicist flung his arm to show that on my right hand was what looked like a bonfire throwing out red sparks in all directions. The sparks described beautiful arcs.

We agreed to make a detour to find out what this was.

Upon reaching the place, we saw scattered lumps of more or less molten iron. The smaller lumps were already cold, but the larger were still red.

"It's meteoric iron," the physicist said, picking up a cold chunk of aerolite. "They fall on the Earth too," he continued. "I have seen them more than once in museums. However, the only thing is, that the name given to these celestial stones, or, rather, bodies, is wrong, especially here on the Moon, where there is no atmosphere. They are never visible here, until they strike the rocky ground and become hot, because some of the energy of their motion is transformed into heat. On the Earth they are discernible almost as soon as they dive into the atmosphere, as friction against the air makes them red-hot."

After crossing the equator, we again decided to deviate towards the North Pole.

The cliffs and piles of rocks were wonderful. Their shapes stood out boldly in precarious positions. We had never seen anything like it on the Earth.

If transported there, to your planet, they would inevitably crash down. But here, they retained their fantastic shapes due to the small gravitational pull, which could not disturb their balance.

We dashed on and on, drawing closer and closer to the pole. The temperature in the crevasses was steadily dropping. But on the surface we did not notice it, because we were gradually catching up with the Sun and were soon to witness its miraculous rising in the west.

We did not run quickly; there was no need. We no longer descended into crevasses to sleep. We did not want to freeze. So we took our rest and meals wherever we made a halt.

We even dozed en route, abandoning ourselves to broken dreams; this was not surprising, since such things happen on the Earth; they are all the more possible here, where standing is the same as lying prostrate (from the viewpoint of gravity).

VI

The moon sank lower and lower, shining down on us and the lunar landscapes with a light now faint, now strong, depending on which face it showed us, that with most dry land or that with most water, and on whether its atmosphere was cloudy or not.

Then came the moment when it touched the horizon and began to dip beyond it, thus signifying that we had reached the other hemisphere, which is never visible from the Earth.

Four hours later it had disappeared completely and we saw only a few illumined mountain peaks. Then even they grew dim. The gloom was wonderful. There were stars galore! From the Earth such a host can be seen only through a very powerful telescope.

It was unpleasant, though, to perceive their lifelessness, their immobility, so far removed from the immobility of the blue sky of the tropical climes.

And the black background was depressing!

But what shines so brightly in the distance?

Half an hour later we discovered that it was mountain peaks. Then more of them shone forth.

We had to climb a mountain. Half of it was shining. The sunlight was there. But as we climbed up, darkness swooped down upon it and the Sun was not visible from it.

This is apparently where the Sun had set.

We quickened our pace still more.

We went swift as arrows shot from a bow.

We need not have hurried so; all the same we would have seen the Sun rising in the west even if we had gone at five versts an hour, in other words, if we had not run at all—what sort of running was it, indeed—but merely walked.

But we felt we had to hurry.

And lo! What a miracle!

In the west an ascendant star gleamed forth.

It quickly increased in size. A limb of the Sun appeared, and then all of it! It rose, separated from the horizon and rose higher and higher.

And yet it was all exclusively for us, as we ran; the mountain peaks behind us faded out, one after another.

Had we not looked at the approaching shadows, the illusion would have been complete.

"Enough, we're tired!" the physicist jokingly exclaimed addressing the Sun. "You may retire."

We sat down to wait for the moment when the Sun, setting in its usual way, would vanish from view.

"*Finita la comedia!*"

We turned over and fell into a deep sleep.

When we woke up we again, without hurrying, merely to have light and warmth caught up with the Sun and no longer let it out of sight. It ascended and descended, but was ever in the sky, ever giving us warmth. When we fell asleep the Sun was fairly high in the sky, when we woke up we caught the rascally Sun trying to slip away, but we curbed it in time and made it rise again.

We were almost at the pole!

The Sun was so low and the shadows so vast that we

froze as we dashed across them. In general, the contrast in temperatures was striking. A place of prominence became so hot that we could not get close to it. It was impossible to cross other places that had lain for 15 Earth days or more in the shade for fear of the rheumatism. It should be remembered that here the Sun, even when almost on the horizon, warms up the sides of the rocks turned to its rays just as much, even twice as much, as the Earth's Sun when directly overhead. Of course, this does not happen in the Earth's polar regions, because firstly, the energy of the Sun's rays is almost completely absorbed by the atmosphere, and, secondly, on your planet it does not shine down so obstinately on the pole as well; there, every 24 hours the light and the Sun circle round a boulder but without losing sight of it.

But you will ask: "What about heat conductivity? Should not the warmth of the boulder or mountain be absorbed by cold and rocky ground?" "It does, sometimes," is my reply, "when the mountain is an integral part of the continent. But many granite boulders, despite their size, have been simply thrown down and have only three or four points of contact with the ground or another boulder. Through these points of contact, the warmth escapes very slowly, or, it would be better to say, imperceptibly. So the mass continues to warm up, while the radiation of heat is very faint."

Incidentally, our difficulty was not these boulders but the very cooled valleys lying in the shade. They interfered with our progress to the pole, because the closer they were to it, the more extensive and impassable these shady places became.

If only the seasons of the year had been more pronounced here, but there were hardly any at all. In the summer the Sun at the pole does not rise above 5°; whereas on Earth it rises five times as high.

And when could we expect this summer, which most likely would allow us to reach the pole somehow?

So by moving in the same direction, trailing after the Sun and making circles, or rather spirals round the Moon, we again moved farther and farther away from this partly ice-cold spot with the hot boulders scattered all over the place.

We desired neither to freeze nor to scorch ourselves! We moved farther and farther away. It grew hotter and hotter. We were obliged to lose sight of the Sun. We had to lag behind it, in order to avoid being baked. We ran on in the darkness, which at first was embellished a little by a number of peaks in the mountain range. Soon they, too, were gone. It was now easier to run: we had consumed much of our food and drink.

The moon, which we had forced into motion, would soon appear.

There it was!

Hail to thee, precious Earth!

We were overjoyed to see it, no joke!

No wonder, after such a long separation!

Many more hours fled by. Though we had never seen these regions and mountains before, they did not arouse our curiosity and seemed monotonous. We were sick and tired of all these marvels! Our hearts ached. The sight of the splendid, so inaccessible Earth only aggravated the pain of recollection, the pangs of irreparable loss. If only we could soon reach our house! We could not sleep. But what would await us there? Merely familiar, but inanimate objects that could only give us more painful torment.

What was the reason for our nostalgia? We had hardly felt it before. Had the novelty, the interest in our surroundings, overshadowed it until they had begun to bore us?

We hurried in the direction of our house, if only to get away from the sight of the dead stars and funereal heavens!

Our home should have been near by. We had established astronomically that it should be there. But despite the

definite indications, we not only failed to discover our familiar courtyard, but even to recognize a single view, a single mountain that should have been known to us.

We searched high and low.

We walked hither and thither—it was nowhere to be found.

We sat down in despair and fell asleep.

The cold awoke us.

We fortified ourselves from our now scanty supplies of food.

To escape from the cold we took to our heels.

As if to spite us, not a single suitable crevasse, in which to take refuge from the cold, ever came our way.

Again we ran in the wake of the Sun. Ran like slaves lashed to a chariot! Ran through eternity!

Through eternity? Far from it! There remained enough food for one meal.

And what then?

We ate our last meal.

Our eyes closed in sleep. The cold forced us to huddle close together.

Where were the crevasses, which were always there when we had no need of them?

We did not sleep long, the unceremonious, merciless and ever-increasing cold awoke us. It gave us barely three hours respite, no chance of a good, long sleep.

Weak and worn out with longing, hunger and the approaching cold, we were no longer able to run at our former speed. We were freezing to death!

When sleep almost overpowered me, my friend prevented me from succumbing; and I restrained from the sleep of death my physicist friend who had taught me the significance of this horrible last slumber.

We supported and fortified each other. And, as I remember now, the idea of deserting one another or postponing the hour of death never for a moment crossed our minds.

The physicist fell asleep, raving about the Earth. I flung my arms round him in an endeavour to give warmth to his body.

* * *

Enticing dreams of a warm bed, of flames in an open fire-place, of food and wine took possession of me. I was with my friends and relations, being cared for and cherished!

* * *

What pleasant dreams! Of a blue sky and snow on the roof tops. Of birds flying past. Faces, familiar faces. A doctor. What was he saying?

"Lethargy, prolonged sleep... his life has been in danger. Considerable loss of weight, terribly emaciated. But the breathing is improved, consciousness is returning. The crisis is over."

All round were happy, tear-stained faces.

In short, I had been in a morbid coma, from which I had just awakened; I had gone to bed on the Earth, and had awakened on the Earth; my body had remained here, in thought I had flown to the Moon.

Still, I was delirious for a long time: I asked about the physicist, talked about the Moon and wondered how my friends came to be there. The terrestrial was confused with the cosmic: I imagined myself on the Earth, then thought I was on the Moon.

The doctor's orders were that no one should argue with me, or irritate me. He was afraid I would lose my reason.

Very slowly I regained consciousness and still more slowly recovered.

It goes without saying that my physicist friend was very surprised when, having fully recovered, I told him the whole story. He advised me to write it all down and to add to it a few explanations of his own.

DREAMS OF EARTH AND SKY

Chapter 1

EXTERNAL STRUCTURE OF THE UNIVERSE

(Introduction)

1. Size of the Earth. If we walk continuously unimpeded and tirelessly, day and night, "over land, over sea", at the rate of 4.5 kilometres an hour, in a year's time we shall have walked round the large circumference of the globe.

If we spend only one second examining each square kilometre of the Earth, it will take 16 years to examine the whole of its surface, and to examine the land alone will take from 4 to 5 years. If we take one second to examine one hectare of land, we shall need 400 or 500 years to do it. Despite the enormous 1,500 million population of the Earth, there is an average of only 3 people per square kilometre on its surface. Including the sea there are about 33 hectares to each person, or about 8 hectares of land alone. There are 2 square kilometres or about 200 hectares of land and sea for every family of six persons.

If we convert the Earth into cubes, and reckon that it will take us one second to examine each cubic kilometre, we would need 32,000 years to examine the whole internal and external mass of the Earth. The size of the Earth compared with the size of a magnificent fairy-tale palace (120 m in length, width and height) is the same as that of the palace compared with a tiny droplet (1 mm in diameter).

The volume of the Earth per person would be equal to that of a planetoid about 10 kilometres in diameter* or a field 1,000 kilometres square and 1 metre thick.

2. *Comparative measurements of the water, atmosphere, mountains and the hard crust.* Imagine the Earth as a polished ball with a diameter as long as the index finger (120 mm). The tiniest granules of sand (0.1 mm) adhering to it will represent the height of the tallest mountains. Let us dip this ball in water, and then shake off the drops; the adhering layer of water will represent the deepest oceans. The Earth's atmosphere which rises to a height of about 300 kilometres will appear on our ball as a layer of liquid 2.5 mm in thickness. But if we only consider the layer of air in which man can breathe, this layer will be no thicker than cigarette paper.

The deeper into the interior of the Earth, the higher the temperature; this leads one to assume that only a small part of the Earth is cold and solid, whereas its internal mass is hot, molten and liquid;** according to our scale, we can think of this hard crust as a thin layer of cardboard about 0.6 mm thick (the thickness of a visiting card).

3. *The sizes of the members of the planetary system.* If we think of the Earth as a small pea (5 mm), the Sun will then be a giant water-melon (550 mm), the Moon—a millet grain (1.5 mm), Jupiter—an apple (56 mm), Saturn—a smaller apple with a thin ring encircling but not touching it, Uranus and Neptune—two cherries, the other planets and satellites—small peas and grains, and the asteroids—granules of sand and specks of dust.

4. *The distances between the members of this system.* The absolute distances separating the heavenly bodies are so immense that the figures expressing them in the usual

* The planet Agatha is no more than 6 kilometres in diameter.

** However, the mass of the Earth is liquid only under the crust, while deeper down the tremendous pressure prevents it from melting, despite the monstrous temperature. Astronomers-mechanics also find that the Earth, generally speaking, is a solid body.

measures are more likely to stagger the imagination than convey anything to it.

For example, the distance from the Earth to the Sun is so great that we should have to walk day and night for 4,000 years to cover it. To follow the Earth along its orbit around the Sun we should have to walk 25,000 years. It would take almost a million years to walk round Neptune's orbit, a distance which Neptune itself covers in 165 years travelling at the rate of 5.3 kilometres a second. The figures we would have to use to show the time it would take to traverse the interstellar spaces can easily be written and pronounced but not imagined.

By reducing the interplanetary spaces in proportion to the reduction in the sizes of the heavenly bodies we find that the pea-Earth will be 180 steps (120 metres), the apple-Jupiter about 500 metres and Neptune a little over 3 kilometres away from the water-melon—Sun.

Thus, in the planetary system known to us (up to Neptune), the Earth is just a pea on a round, 8,000-acre field.

The grain-Moon will be less than 150 mm distant from the Earth.

5. *The motion of the planetary system.* All these apples, peas, grains, granules of sand and specks of dust not only spin like tops but also move round the water-melon-Sun which in relation to them is almost motionless and only rotates.

The planetary system lies, as it were, in one field which carries away in a straight line all the movable and immovable objects lying on it.

It is remarkable that the axes of rotation of almost all the members of the planetary system point approximately in one direction; they seem to be placed on the imaginary field. Remarkable also is the fact that the rotation and motion round the Sun take place in one direction. If we stand at the North Pole of the Earth or the Sun, we shall see that they are moving counterclockwise. The satellites move in the same way.

6. The speeds of planets. The pea-Earth rotates on its axis once in 24 hours and takes one year to revolve round the water-melon-Sun. The closer the planets, or the spheres which represent them, are to the water-melon-Sun the faster they move, and the farther away they are the slower they move. The same is also true of the planetary satellites. For example, Jupiter with its satellites forms a miniature planetary system, except that in this case the central body (Jupiter) does not emit its own light.*

Although our peas and cherries move very slowly and rotate altogether sluggishly, the true speeds of these movements are far from what they appear. For example, the extreme points of the Earth, which are some distance from the axis of rotation, move with the speed of bullets or shells fired from the biggest guns, the large planets rotate still faster, and the total motion round the Sun of all the points of a heavenly body is even hard to imagine. For instance, the Earth travels at a rate of about 27 kilometres a second. If only a particle of the Earth, equal in size and mass to a small bomb, were to hit an immovable wall, the force of impact would be 2,000-3,000 times as great as the distructive force of the finest artillery gun. If a stone were thrown from the surface of the Earth at the speed at which the Earth moves round the Sun, it would forever move away from the Earth and, hurtling eternally in the same direction, would lose less than half of its initial speed.

7. An idea of the speed of light which will help us in our narrative. Light travels at such a speed that it can circle the Earth 7 or 8 times in one second. It travels through interplanetary space with about the same ease as a fly flies from one end of a room to another, or a bird from one part of a town to another. For example, a ray of light reaches the Earth from the Moon in about one

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* If Jupiter does emit light, it does it very feebly, and its luminescence is like that of an active terrestrial volcano, only on a grandeur scale.

second and the Earth from the Sun in 8 minutes; it travels through all the interplanetary space known to us—from Neptune to the Sun and back—in 8 hours. Thus the planetary system is really not so small, if even for the swift ray of light it represents a greater distance than 30 kilometres for a hiker (since the hiker will cover this distance in less than 8 hours).

Indeed, light moves 500,000 times as fast as a cannon ball which would take 400-500 years to cover the distance a ray of light travels in 8 hours.

8. *The Milky Way.* The Milky Way is a galaxy of thousands of millions (literally, and not in the sense of a multitude; I shall always try to express myself exactly) of stars or suns occupying in aggregate a disk-shaped space, like a bun or a flattened sphere, and all tremendous distances apart from one another. The whole starry sky visible to the naked eye, together with the nebulous band of stars distinguished only through telescopes, is the Milky Way. The stars which appear large are closest to us, the smaller ones are farther away, while the smallest ones appear as a whitish mist because of their remoteness. On our Earth we are about in the middle of the Milky Way. Across it we see only the relatively close stars which therefore do not merge into a single nebulous mass. Lengthwise along the Milky Way we observe so many and such remote stars that they appear as a mist to us.

The Sun is one of the stars of the Milky Way, but we are so close to it that it blinds us. All stars are like this if we get close to them; the satellites of the suns*—the planets and the satellites of the planets—are an exception. With the naked eye not more than a dozen of them are visible. Illumined by the Sun and relatively close to us they look like stars, but if we came closer to them, they

* If the satellite of a sun (i.e., of a star) is very large, it has not had time to cool and is therefore radiating light, like a sun; such a system is known as a binary star; there are also multiple or complex stars.

would turn out to be mere planets, like the Moon. Through a telescope several hundreds of them can be seen; they are all satellites of our Sun; the satellites of other suns cannot be seen because of their remoteness.*

The distance to the nearest stars is so enormous that even by reducing it, as we reduced the size of the Earth by making it as small as a pea, we should still find it to be thousands of kilometres. Hence, the stars, according to our picture (our miniature), are self-luminous water-melons of different size located thousands of kilometres apart.

But how bright these water-melons must be to be seen thousands of kilometres away! Some of the stars in our model will therefore appear like mountains. For example, the diameter of Sirius will be about 6 metres.

By imagining the solar system as the average space occupied by a star in the Milky Way, we can say that the Earth in the latter is like a drop of water in the ocean.

This space, or distance from the neighbouring stars, is so enormous that even a swift ray of light takes years to traverse it. It takes light thousands of years to traverse the entire Milky Way known to us with the help of telescopes. The smallest of the infusoria, barely visible through a microscope, is of incomparably greater significance in the waters of the Earth than is the Earth in the Milky Way. I mean, of course, not the spiritual significance of the Earth, but only the space it occupies.

9. *The grandeur of the Universe.* The Milky Way has so many stars that, if they all merged into one, we would have a sun that would occupy the whole planetary system at least as far as Jupiter.

But there is more than one Milky Way; there are numerous similar galaxies of stars. From the Earth, i.e., from our Milky Way, these galaxies appear as rather rounded

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* Except the enormous luminous ones.

telescopic nebulous spots.* Their number may be as great as the number of stars in the Milky Way.

The distance between the galaxies is immense and at the speed of light it would take millions of years to cover it.

Had they appeared 100,000 or 200,000 years ago we would not be able to see them today because in that time a ray of light would not have succeeded in reaching us. They must have appeared millions of years ago if we see them as we do today<. . .>**

A group of galaxies in all probability constitutes some other unit of a higher order. . . .

10. The movement of stars. I said that the imaginary field of our planetary system carried along, as it were, by a storm, moves in a straight line so that the Sun also traverses several dozen kilometres per second. All the observed stars also have similar speeds but they move in various directions. But the speed of the remote stars is extremely difficult, as yet even impossible, to measure. Some stars travel at the rate of hundreds of kilometres a second but though they move so fast, the naked eye would never observe any movement even in the course of thousands of years.

Hence, the incorrect, although generally used expression "fixed stars".

The reason for this is the enormous distance between the stars. If the nearest star decided to run with the speed of light round the Sun or round us (which is the same thing since, relatively speaking, we are at almost the same point as the Sun) it would need years or even dozens of years to do it. How long, then, must a star travel at its

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* That such a spot is not a rarefied gas—father of suns and planets—is evident from its characteristic spectrum which differs from that of gas and is typical only of incandescent solid bodies and stars.

** The angular brackets here and below show a cut in the text.—Ed.

natural speed which is hundreds of thousands of times less rapid!

To do this a star would need millions of years, whereas thousands of years would only see it through a small fraction of a degree.

If we lived and thought amazingly slowly so that for us a century turned into a second, we would see with our own eyes the wonderful sight of stars crawling in different directions. Some of them would grow brighter, others dimmer. Some would pass so near that their light would blind us.... But the Milky Way would long appear unchanged because of its remoteness.

11. A view from different points of the Universe. What will a man see as he moves at an arbitrarily chosen speed from one point of the Universe to another? Since he starts from the Earth he will see, in the first place, how rapidly the Earth grows smaller, after appearing at first as a greyish bowl, into the interior of which he is looking, and occupying a little less than half the sky. The bowl grows smaller and smaller and changes into a gigantic saucer.

The Sun will change much more slowly; to avoid being burned, we shall move away from it, in view of which we shall dress more warmly. The appearance of the starry sky will long remain the same; but now the Sun has changed into a star; the Earth and the other planets have long become invisible; the pattern of the constellations is clearly not what it was; only the small stars and the Milky Way are the same as before.

We shall move faster, and all the large stars will appear to be moving, like trees to a person who is travelling swiftly past them; some of them will draw nearer and shine brighter, others will move away and totally disappear. We shall go on still faster because we have seen enough of this change of scenery. If we move along the Milky Way bun, the mist on one side of it will gradually turn into stars and finally disappear. We shall see stars

all around us, but the Milky Way, in a semi-circle, is only on one side.... Later we shall see the stars also only on one side. They will grow increasingly dimmer and smaller, until they disappear and only the arc of the Milky Way will remain, and this, too, will gradually diminish and become a nebulous spot.

I look hard and see many such nebulous spots all around. These are other galaxies. I see no stars or Sun, but only these very faint, whitish spots. I fly past the whole association of spots leaving them to the side, in a heap. The heap grows smaller and disappears. Total darkness. Can this possibly be the end of everything, the end of the world? Not by a long shot! We fly faster in the same direction, and new association of spots comes into view out of the darkness. Everything is repeated in the reverse order, and we enter a new world, the existence of which we can only guess at.

And how many worlds like this can there be, how many tranquil associations of tiny spots are there in the whole of infinity?!<. . .>

Chapter 2

UNIVERSAL ATTRACTION

12. How weak is the mutual attraction of terrestrial bodies. A stone falls into a well, and a weight presses against the floor—this is gravity. Its cause is as yet the unexplained property of matter to attract other matter, like a magnet attracts iron, but much more weakly. Although many attempts have been made to explain gravitation, all the explanations proved unsatisfactory* and hence were discarded. In addition, they introduced principles which were no more intelligible than the mutual gravita-

* The most ingenious of these explanations was offered by Georges-Louis Lesage in 1818.

tion of all bodies at a distance. Since the acceptance of some inexplicable principle is inevitable, it is best to accept a principle like the law of gravitation which is perfectly clear, is expressed mathematically and has already explained a whole mass of phenomena.

The force of attraction of a given spherical or point mass diminishes (the greater the distance from it), as does the intensity of light, the farther the distance from the spherical source. But there is apparently very little in common between gravity and these partial forces. Indeed, gravity does not disappear, does not become exhausted, does not depend on temperature or lighting and does not require time for its propagation. Otherwise an incandescent or luminous body, for example, would be attracted by the Earth with an inconstant force, i.e., it would weigh differently, something that no one has ever yet observed. Further, different parts of the globe, being differently heated, would display a tendency to explode or to distort the shape of the Earth. Differing physically, the Earth and the Moon would be unable to move in concert round the Sun.

Thus all bodies attract each other at any distance.

But only very precise and difficult experiments* reveal the attraction of terrestrial bodies to one another, because even the attraction of such masses as mountains is extraordinarily feeble. The mass of the Earth is enormous, and that is why we easily notice its attraction.

The attraction of small bodies would be revealed in their drawing nearer if this were not prevented by friction. Two stout men at a distance of 1 metre attract each other with a force of 0.05 mg. This force may bend a hair one metre long but will never break it; it will not even break the finest cobweb. Can it, then, possibly move two

* The most precise experiments on the attraction of spheres were performed by Cavendish and, on the attraction of mountains, by Maskelyne. Airy's experiment in mines is also well known.

men, overcome their relatively considerable friction against the ground on which they stand?!

Spherically shaped and with their centres one metre apart, one ton attracts another with a force of 6.66 mg.

12_1 *The power and law of attraction of a given mass depends on its shape and density.* Don't imagine that the force of gravity of a given mass depends entirely on its size and the distance and mass of the attracted body! Only for spheres or material points is the attraction proportional to the product of the attracting masses and inversely proportional to the square of their distance apart. For bodies of a different shape the laws of gravitation are pretty capricious. For example, an endless plate limited in thickness by two parallel planes, and, consequently, also an infinite mass, should attract with an infinite force, and yet this is not at all the case; the attraction is quite weak, depending on the thickness and density of the plate; it is at a right angle to it and is everywhere the same at every distance from it.

If the distance of the body in relation to the size of the plate is small, then for purposes of calculation it may be assumed to be endless. We saw, for example, that for each inhabitant of the Earth there is a mass equal to the mass of a flat field 1,000 kilometres square and 1 metre thick (its density must equal the average density of the Earth, or 5.5). A man walking along this field will experience over almost the whole of its area and on heights up to several dozen kilometres the same attraction (as if the plate were endless) which is 6 million times less than the Earth's attraction or 2,000-3,000 times less than that on the surface of an asteroid 6 kilometres in diameter (Essay 31).*

To exert an attraction equal to that of the Earth the endless material plate of the same density as the Earth must be 4,000 kilometres thick (2/3 of the terrestrial radius).

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* Agatha.

But, on the other hand, the attraction of such a plate does not diminish at any distance and does not change its direction (of course, on the other side of the plate the gravity will be in the opposite direction).

The Earth flattened into a disc exerts less attraction, the thinner the disc. Thus, theoretically, the attraction of the Earth can be reduced at will. The disc can be gently revolved so that the interattraction of the parts of the flattened planet does not bend it into a tube or turn again into an astronomic drop, and the centrifugal force will eliminate the attraction and prevent the destruction of the disk.

Loosening the spherical planet also reduces the attraction on its surface and inside it; for example, an eightfold decrease in density, without affecting the mass, reduces the attraction fourfold; a thousandfold loosening reduces the gravity hundredfold.

Sometimes enormous masses of whatever size produce no mechanical effect on bodies.

Thus an empty sphere with concentric walls and an empty cylindrical pipe with similar walls* produce no mechanical effect on bodies placed inside them, not only in the geometrical centre but anywhere at all. The external attraction of a pipe is inversely proportional to the distance of the body from its axis, whereas the external attraction of a sphere is inversely proportional to the square of the distance from its centre.

13. The effect of gravitation on the shape of planets; gravity on different planets. We know how amazingly large the heavenly bodies are, and they alone clearly reveal their attractive force.

Owing to gravitation all suns and large planets are in the shape of almost perfect drops. Even if the heavenly bodies were cold and made of the strongest material, for

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* True for endless pipe.—*Ed.*

example, steel, they would, if they were any shape but round, break up and become rounded. They would retain relatively negligible unevenness, like the granules of sand on the polished ball.

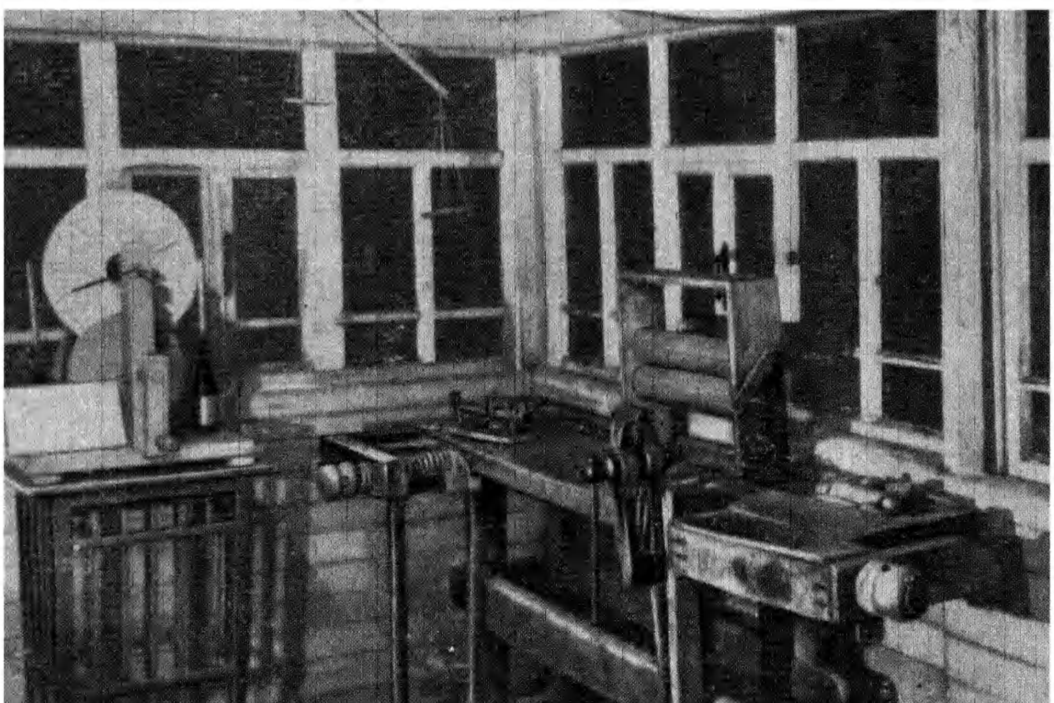
The attraction on the surface of different suns and planets varies with their mass and density.

If a man lifts 80 kilogrammes and jumps over a chair on the Earth, he will lift a cow and jump over a high fence on the Moon. On the Sun he would be unable to stand up; he would fall and be killed by his own gravity which is 27.5 times greater than on the Earth. On Mars and Mercury he would lift 160-240 terrestrial kilogrammes and would easily jump over a table. On Jupiter, without carrying any load, he would barely drag his feet along, as though he were carrying a stout man too heavy for him. On asteroids he would lift houses and jump over the tallest trees, belfries, forests, wide ravines and more or less tall mountains, depending on the size of the asteroid he was experimenting with. Finally, on aerolites few dozen metres across he would feel no gravity at all.

The force of gravity on different planets limits the height of the mountains, buildings and organisms. On the Moon the mountains would be six times as high as they are on the Earth, and if they are as high as those on the Earth it is only accidental or due to the looseness of the material forming the lunar mountains; after all, on the Earth the mountains do not reach their maximum height. On asteroids the unevennesses are so enormous that they exceed the size of the planets themselves, and so their shapes are infinitely varied and may not be spherical at all. Some of them are shaped like an irregular stone or fragment, others like a disk, a ring, etc. (This is just a mere supposition: their shape cannot be distinguished by the telescope. We have arrived at this conclusion partly theoretically and partly because the strength of their light is deceptive). As they rotate, they reflect sometimes more and sometimes less of the rays of the Sun and

Konstantin Tsiolkovsky, 1910

Tsiolkovsky's old house in Kaluga where he lived from 1904 to 1932 and which has been turned into a museum



A corner of Tsiolkovsky's workshop

through the telescope appear to the observer as variable stars of every possible size.

If a man on the Earth were two to three times his present size (his shape being the same) he could hardly drag himself along, and if he were six times his present size he could only lie on a soft couch or stand up in water; but on the Moon the same 12-metre giant would feel perfectly at ease.

Giants the height of a very tall belfry would move about easily on asteroids. A giant whose hand could touch the top of the Eiffel Tower and who weighed 334,000 tons would skip and frolic like a goat on an asteroid 150 kilometres round (supposing it to be spherical) and having the average density of our Earth. On the other hand, only Lilliputians 6.6 cm tall could live on the Sun.

It will be observed that these conclusions about organisms of this structure are strictly mathematical.

The effect of gravity on the shape of the planets is complicated because they rotate round their axes.

Because they do so, the Sun and the planets are more or less flattened at each end of their axes. If the rotation accelerated, the planet would first turn into a flat bun and then into a ring with a central spheroid; the ring could break up into separate parts revolving round the central body.

Perhaps this is how Saturn with its rings and the planets with their satellites came into being; perhaps this is how the whole planetary system was formed.

14. What would happen to the Earth, if the Sun no longer stretched its attracting arm towards the Earth? Gravitation keeps the planets near the Sun and the satellites near their planets and does not allow them to escape into cold and infinite space.

If the Sun were not retaining the Earth as if with a rope, then within one year every living, unprotected earthly thing would perish; the Sun would become a very bright star, and its luminosity and heat would be 37 times

less strong than it is today. Within two or three years the temperature of the atmosphere and external parts of the planet would scarcely differ from that of outer space (about 200° below zero); then light—the last consolation—would vanish, too, just like a playful electric sun; nothing would remain but ice-cold night and the sky, beautiful but sad. The oceans would freeze and the air would liquefy and destroy man, trying to keep warm in caves—his last refuge.

Everything would straggle off in different directions and the planetary system would cease to exist. And if in a few hundred thousand years, the planets with their hapless inhabitants encountered some other sun, which would be most unlikely, they would immediately lose it again in the space of two or three years, in so short a time for the extinct or, rather, the remaining spark of life to spring up again.

See what a role gravitation plays!

Like light and sound and heat and magnetism it rapidly diminishes with distance and according to the same law.

As gravitation recedes from its source, as it were, it disperses, dissolves into expanding space.

The Earth is drawn to the Sun with a force 50,000 times less than the force which would attract the same Earth if it were lying on the surface of the Sun; and yet this force is sufficient to change the natural rectilinear motion of the Earth into a circular, or to be more exact, an elliptical motion.

Very rapidly moving heavenly bodies cannot be long detained by the Sun; it diverts them from their straight course, but not for long: speed gets the upper hand and the bodies move off into infinity. These bodies are the comets. Some return to the Sun, their course (trajectory or orbit) being a greatly elongated circle (an ellipse, like a long bleb in a bad window pane).

15. The mutual attraction of the stars and the Milky

Way. Where is there no gravity? When we move away from a candle its light grows feebler; gravitation depends on distance in exactly the same way.

If we move 10 or 100 kilometres away from a candle we finally lose sight of it; similarly, if we move far enough away from the source of gravitation, our sense organs completely lose their ability to determine or even notice the infinitely diminished force of gravity.

Interstellar space, especially the space between the "spots" of the galaxies is of this kind.

Even between the stars gravitation is at least 100 million times as weak as the Earth's force of gravity at its surface. This means that if a motionless body were placed there it would acquire within 24 hours a speed of 9 mm a second.

Within a year this speed would be no greater than that imparted to a man jumping from the height of a table (5/6th of a metre).

The attraction between the spots of the galaxies, or the accumulations of stars, is 1,000 times as weak as the foregoing; it follows that in the course of a year man acquires the same speed there as he does when falling from a height imperceptible to the eye (1/1,250 mm). The speed of the stars is so great (Essay 10) compared with the effect of gravitation that even if their course is curved the curvature is very small. Perhaps stars are incapable of escaping the field of gravity of their own galaxy; but they certainly cannot escape the sphere of a neighbouring star and assume a distance mid-way between them.

Although there are numerous "binary" and even "ternary" stars ("compound stars"), or stars revolving round one another, as the Earth revolves round the Sun or the Moon round the Earth, and which form systems, like the planetary system, but composed only of self-luminous members, they are nevertheless exceptions which came into existence because of the relatively negligible distance between such stars.

16. The apparent absence of gravity. There is no need to climb so high in order to witness phenomena in the absence of gravity.

Let us imagine ourselves on a tiny little planet revolving round the Sun somewhere between Mars and Jupiter, i.e., in the zone of asteroids or outside it, closer to the Earth. At any rate there can be no shortage of these tiny planets, and if they can't be seen through a telescope it is only because they are so small. In the planetary system, all round the Sun, there is plenty of planets the size of a pebble, pea or speck of dust which from time to time cross our atmosphere, becoming heated through air friction and shining like stars (aerolites or "shooting stars"); sometimes they strike against the hard surface of the Earth. We collect them up and keep them in museums.

And so, we are on a tiny planet a few dozen metres in diameter; we can disregard its gravity, since indeed with a diameter of, say, 12 m and a density equal to the mean density of the Earth (5.5) it exerts at its surface an attraction 1,000,000 times as weak as that of the Earth.

The question is, will our weak gravity alter on this tiny planet under the influence of the Sun's attraction?

The Sun imparts a certain motion to the planet, but it imparts exactly the same motion to our bodies; the Sun alters the motion of the planet, but it also alters the motion of our bodies. Hence, if we, for example, did not come into contact with the planet's surface prior to the Sun's attraction, then after it sets in we would neither draw nearer to, nor recede from the planet. This shows that our relation to the planet does not alter under the effect of external gravitation (no matter how many forces of this kind there may be and regardless of the direction in which they attract), as long as the distance between their centres and the group of bodies under observation is large in comparison with the size of the group itself.

You will understand this if you think of a handful of wood chips being carried away by a current, the position

of the wood chips in relation to each other remaining unchanged for a long time. We and the tiny planet are the handful of wood chips, the attraction of the Sun is the current.

It follows that the apparent absence of gravity may be encountered on every small asteroid measuring a few metres across. But the attraction of even large masses, of any enormous size, may also have no influence on other bodies.

Calculations show that a hollow sphere produces no mechanical effect on bodies located inside it or on its internal surface. If our planet is a hollow glass sphere containing air and plants to purify it, we have a fine arrangement for performing experiments. True, the air itself attracts, but this attraction is relatively negligible.

Our glass sphere revolves round the Sun between the orbits of Mars and Jupiter. Won't this be a little too far? Can't we create, on the Earth or very near it, conditions in which there will be no gravity? Yes, we can; but let us keep it a secret for a while and imagine that, by some miracle, the Earth's gravity has disappeared. Let us describe what will happen then. Man is in such close affinity with his environment that there can be no more suitable method for describing the phenomena occurring without gravity. We shall therefore try to preserve the entire surroundings with only a few exceptions.

Chapter 3

DESCRIBING VARIOUS PHENOMENA IN THE ABSENCE OF GRAVITY

17. Vanished gravity. The Earth has lost its gravity: instantly the air disappeared, rivers and seas became still, boiled up or frozen over; plants shrivelled, animals perished. Much more would occur, but not everything can be foreseen or described.

There is no gravity, but let us suppose the air and the seas and rivers remain. This is not easy to arrange, but anything can be assumed. So let us, incidentally, assume that the centrifugal force of the Earth's daily revolution has not hurled from its surface everything that was on it. For our purpose, the Earth must not rotate, the air must be retained from dissipation by a strong crystal envelope like the imaginary sky of the ancients. Then, the moisture will remain, the plants will not shrivel nor the living creatures die.

Let us further assume that the terrestrial world has become a hollow sphere, turned inside out. The air, trees, houses, people, rivers—all are on the inside of the sphere, while the masses of the Earth gush out of its bowels. In this way, gravity will be naturally abolished (Essay 16).

Now let us place a small sun in the centre of our new habitation and make the best of our eternal daylight.

However we look at it, we are living in our usual conditions, the only thing lacking is gravity.

18. What happened inside the house (subjectively). The previous night we had gone to bed in the ordinary way, but on this particular day we awoke in an environment devoid of gravity.

It was in this way. I awoke with a dreadful sinking of the heart, the sort of feeling that assails anyone falling from a height. I flung off the blanket and then observed that the bed was standing on end, yet I hadn't slipped off it. My friend, sleeping in the same room, was awakened by the same sinking of the heart and a feeling of coldness: his mattress had springed him and his blanket completely off the bed and he was floundering close to the ceiling, unable to cover one half of himself with the blanket and shivering in the cold morning air.

My blanket, somehow caught up in the bed, was scarcely covering me, and my body hardly touched the mattress.

I had a constant feeling that I was falling. My heart sank ... I looked round ... everything was in its place .... I calmed down; then I dozed to be awakened with the same sinking feeling. Gradually the intervals between these sinking feelings grew longer and the false sensation of falling weakened. I got up in order to dress, when suddenly I found myself gliding fairly smoothly to the opposite wall. My heart thumped alarmingly ... I could no longer distinguish floor from ceiling, top from bottom. The whole room and the garden and sky glimpsed through the window seemed to be whirling round for no reason at all. I was in a dreadful state of indescribable confusion.

I travelled through the air to all the corners of the room, to the ceiling, the floor, and back again; I tumbled around in space like a clown, only involuntarily; I knocked every limb on every possible object, setting in motion everything I hit into. The room swam about, bobbed up and down like a balloon, receded, struck me, came to meet me. My head was in a whirl of confusion, and all the time there was that ghastly sinking of the heart.

We tried to grab various articles of apparel, but the movement from place to place continued, and everything whirled and floated about in the air; objects knocked against one another, against us, against the walls.

Our unmentionables floated about the room in a friendly embrace with a hat; coat and scarf gracefully writhed and quivered; shoes and socks lay in separate isolation. As I moved after one article, another hid itself in some nook, revelling in its solitude.

We were no good at controlling our direction and beat about like flies in an oil-lamp glass. We continually forgot to cling to something and to hold fast to the smaller articles we required for dressing. Round the room we tumbled, our trousers only half on, forgetting to catch up our jackets and causing ourselves additional trouble.

Books from the shelves, various small objects, all seemed to be alive and were sedately roaming round

with apparently no serious intention of ever coming to rest.

The room was like a fish-pond; it was impossible to turn without knocking against something: tables, chairs, sofas, mirrors were suspended in air, each in its own fashion, performing stately twists and turns in somewhat unpicturesque disorder, yet as though in a state of reverie. The books fluttered open, their pages puffed up as if to say: "Read us on both sides; we've brought ourselves to you out of sheer boredom."

If we pushed aside some plaguesome object as it dived for our eyes, brushed the nose, ticked the ear or tweaked the hair, it thrashed about from corner to corner, striking us and knocking into other objects with the extraordinary fury of one possessed, as though angered and paying us back for our insolence; and its capers only doubled the general confusion. Gradually it quietened down and gently nudged a doll as if to say: "Why aren't you joining in the row?" And the doll, too, joined in the commotion.

My watch, captured by its chain by sheer chance, writhed and squirmed like a snake as it showed us the time and, by way of reward, was returned to my waistcoat pocket.

It was quite impossible to restore order: the more zealously we tried to set things to rights, the more they fell into confusion. The pendulum clock stopped and refused to start despite all our efforts. The pendulum would not swing. A jolt sent the water out of a decanter flying across the room like an oscillating balloon until it burst into drops as it struck some object, splashing against and oozing down the wall.

Nor were things in their accustomed place in the other rooms, but as no one tried to restore order, at least they did not behave wildly; they did not shift about, leap in the air or knock other things about. On closer scrutiny, however, we did notice some slight disturbance.

The garden looked much as usual, unlike the chaos indoors: the green, swaying trees, the rustling grasses, the

fragrance of the flowers reaching us through the net curtains over the open window. I hesitated about opening the curtains for fear of losing articles which had several times approached the windows, peeped into the garden and, as though regretting they could not promenade further, had very slowly withdrawn.

We became a trifle used to our new situation. I no longer cried out every time I found myself head downwards, between "sky and earth"; my heart no longer sank from time to time. We learned to remain on one spot or to move in a desired direction.

What we could not learn was how to float around without revolving; we pushed off and without fail began revolving, although slowly; it was dreadful because on all sides everything appeared to be going round and round till the head began to spin. It was equally difficult to rid ourselves of the idea that the house itself was tottering and mobile. It was hard to convince ourselves that we alone were moving. When we pushed off it seemed as though we had given the room a shove and it was floating away, just like a skiff, in the direction we had shoved it.

19. An unsuccessful leap that ended safely (subjectively). Do not imagine, dear reader, on the basis of the preceding essay that in space, where there is no gravity, bodies have the property of being set in motion of their own accord. Quite the contrary. In a gravity-free environment, a body which has no motion will never acquire it without the action of some outside force, and on the contrary, a body in motion retains its motion forever. Everything in our room was in a turmoil because where there is no gravity there is also no friction, which largely proceeds from gravity itself, owing to which the least effort, the slightest puff of air is sufficient to move an object from its place and make it move eternally in one direction and to revolve eternally.

It is very difficult to put down an object without somehow giving it an accidental jolt. Try putting a samovar

down straight on the floor! It seems that nothing could be easier, yet you will not be able to do it, even if you yourself are held steady.

While your hands hold the samovar everything is splendid, the samovar stands up; but the moment you withdraw your hands it begins very, very slowly to turn to one side and lean over; you will find that within five minutes it is an inch off the floor, no longer touching it. The whole point is that when you withdrew your hands, you imparted motion to the samovar through the involuntary, imperceptible shaking of the hands, and in the course of time the samovar reveals this motion.

If the objects in our room gradually settled down, it was due to the resistance of the air and the loss of speed through impacts.

The wandering of these objects in the free medium can be compared to the motion of motes in a pond. Note how agitated they are, eternally stirring, eternally crawling about, yet in the water they encounter relatively terrific resistance.

From wall to wall, not without mishaps, we floated in broken lines through all the rooms, until we came outside to the doors of the porch. Here we paused to think. A wrong move and we would be flying into the "sky". And how would we return? We leaped into the garden; we had miscalculated (leapt too high) and flew upwards, not even brushing the tallest tree.

Vainly we stretched out an arm to grab a tree top: the trees receded, descended, as though falling down from us. In addition, the flaying of arms and legs in the air caused me to begin to revolve; it appeared to me that the entire, vast terrain from which I was receding was also revolving: now it was straight over head (an abyss beneath me), now it was a wall, now a mountain pointing skywards....

I was alone; my friend had lagged behind, although he had shouted: "I'll catch up with you in a second!" I

wanted to wait for him, I swung my arms about, but it was quite useless.

I knew I was flying but my senses could not register the fact; I seemed to be absolutely motionless and the Earth to be moving. What I had feared was now happening. I was being carried away into infinite space to become a satellite of the Sun, in a word—a planet.

What I had once thought about long ago as I lay in the grass looking up into the clear sky came to pass. "What if I fall off into what is *there*?!" had been my thought. And now I was falling, the approaching air ruffling my clothes. Bah! This air should stop my planetary flight.

Yet an hour passed and I was still flying. I made desperate efforts, but in vain. My friend had disappeared from sight.

Something appeared far ahead of me ... closer and closer ... a barrel! It bashed into me. Ah, deuce take it! A lucky trail it followed. The impact sent me flying in the opposite direction. Splendid! Back ... to the garden ... to my friend flying helplessly.... I grabbed his outstretched leg and together (not particularly gracefully) we plunged into the shady coolness of the garden.... The leaves tickled our faces ... but we paid no attention to anything and, tortured by anxieties and with the caution, born of our unfortunate experience, made our way from tree to tree, from branch to branch to the summer-house where we locked ourselves in so as not to get lost and gave ourselves up to sleep.

If anyone had seen us sleeping, he would have likened us to corpses floating in the breeze. Obviously there is no conceivable bed quite as soft as that in any part of an environment free from gravitation.

20. In the garden. We glided along close to the ground, barely brushing the grass. Like butterflies we touched the flowers and delighted in their fresh fragrance. Like birds we flew among the shrubs and trees, clutching at them,

then after circling around a few times, hesitated like young birds swiftly alighting on a twig, and then stood still.

If you cannot manage to keep still hanging on to a supple sapling and make a half or even a quarter turn, the direction of your motion will change, but not altogether. It was good lying motionless close to the ground; sometimes we felt we were immersed in wonderfully clear water or lying on the finest plate glass.

In order to move faster it is convenient to kick off from the sapling, rather like I used to when I swam on my back. In this way I flew through the air at ten to fifteen kilometres an hour. But the air resistance soon slowed me down, and I found it better to kick off more often and more gently. Because of this resistance, and starting with this initial speed we could scarcely be carried beyond the atmosphere. Incidentally, calculations show that the motion of a body never ceases when it is in a liquid medium (or in the air), and, although the speed rapidly diminishes, it does not diminish to zero; in these conditions the body traverses infinite space in an infinite space of time. Yet air currents, terribly weakened by the absence of gravity, could freely carry us away.

21. What happened in the town. A town acquaintance dropped in, or rather he flew into our garden in a state of agitation and, while nibbling at a ripe apple, gave us the essence of what was going on in the town. Things were in a terrible mess: the horses, carriages, people and even completely furnished houses, where their foundations were poor, were flying through the air as lightly as specks of dust and bits of fluff. The ladies had tied tape round the lower part of their skirts, because they had little use for their legs, and also because the situation was embarrassing. Some were wearing male clothing—emancipation of a kind!

... Water flowed out from rivers, ponds, and wells, was absorbed by the ground or flew about in the shape of spheres of various sizes, like soap bubbles, only not so

fragile. When a particularly enormous water sphere touched someone not sharp enough to avoid it, it drenched him from head to foot, and he had to shake himself dry like a sheep-dog. Subsequently, everyone learned to travel safely, but at first it was amusing and at the same time bitter experience....

Because of capillary attraction the subsoil water, no longer restrained by gravity, rose to the surface. The plants obtaining enough moisture now could do without rain. Indeed, we found the ground damp everywhere, like it is after rain, yet the grass and leaves were dry.

There was a clamour and uproar everywhere; everyone was flying about, but never for a moment in the desired direction; people were crawling about, spinning round; there were shouts of horror, exclamations of surprise ... and peals of carefree laughter.

Creatures that had never been known to fly—cats, crawl-insects, yelping dogs—were tumbling about in mid-air. And their flight was peculiar—upwards, ever upward for they were evidently not adjusted to the new conditions. An entire herd of cattle was mooing in the heights beneath the clouds. A company of soldiers with no mind for discipline, some upside down, some sideways-on, others swaying like rickety posts; one standing on the head of another ... and the whole lot like a handful of matches, scattered untidily on an invisible cobweb.

22. *Out in the open.* We moved along smoothly, at one and the same height; when we came to a ravine or a river the ground dipped below us. At the bottom, the remaining water sparkled and assumed marvellous, fantastic shapes. But there was no occasion for us to fear: we did not fall into the abyss, but floated over it like clouds, soared like birds, fluttered like bits of fluff caught up by a strong wind. Sometimes we brushed lightly against a wall or a hill; but pushed off, soared up and alighted on it so imperceptibly that it was as though the wall or hill had itself obligingly descended. We clutched at the grass, shrubs

and stones on the hill sides in order to change our direction and again made off in a horizontal direction.

But our motion gradually slowed down; we had to impart ourselves motion again through some kind of impetus; for this reason it was not convenient to fly high, since there was nothing to kick off from.

Sometimes we flew head downwards, and the earth stretched above us like a ceiling, with overturned forests and mountains, while beneath our feet was an abyss into which, however, we did not fall. When we flew in a recumbent position, it seemed as though we were ascending or descending alongside a wall, the Earth standing to the side, like a wall, the trees also sideways-on; on all the other sides of us there was a chasm!

Then all the illusions vanished, we no longer regarded the Earth as a capricious spinning-top and began to realise precisely how we were moving about. In this way does the wayfarer floating in his boat down a river gradually comes to the realisation that the river banks are not really slipping past him, but that he is moving past them.

In time we learned to move at any altitude and in any direction. For this we used wings which had no weight of their own, despite their large surface, and which sped along at our backs without the slightest effort. The wings rid us of the unpleasant rotation, and we found that, like birds, we could easily set ourselves in motion and with the minimum expenditure of effort. We easily flew 10-12 kilometres an hour without feeling particularly fatigued. In a recumbent position we could move twice as fast. Since we tired most from the variety of frolicsome evolutions we performed, we settled ourselves on a hill, rested, ate our fill, then dozed a little or simply admired the beautiful view. During our meals, bread, meat and pitchers of water—all of them rested in the air as they would have been set out on the table.

It was wonderful to fly over mountains, through dark ravines, over forests and water.... After a few days of

playful travel, we found ourselves in a warm climate. We protected ourselves from venomous snakes, beasts of prey, and the like, by flying inside an iron net. Actually, the poor dumb creatures were entirely disarmed and just as helpless as the population had been when the upheaval started. Most of them had perished and the rest were doomed, too, because it was only by chance that they found food and water.

Our food consisted of delicious nuts and fruits which, it goes without saying, we procured without any difficulty.

The people became more and more accustomed to the new conditions; the animals perished because of their limited understanding, the plants survived because of their total lack of understanding.

In forest clearings we sometimes encountered men and women performing beautiful folk dances. We heard human singing and music in the air at the height where the larks hover and sing. And here the poses the dancers' bodies assumed were a joy to behold. At times we were so entranced that the dancing and singing plunged us into an imaginary fairy-tale world of mermaids and other fabulous creatures.

Sometimes we witnessed the tragedy of an unfortunate ruminant dying of starvation within a few metres of thick, succulent grasses. By kicking about violently in the air it had, accidentally, of course, scarcely approached the ground and begun to crop the grass than a new, foolish movement of the legs carried it up into the air again, and it found itself still farther from food than it had been before.

It was even worse with the beasts of prey (the birds of prey adapted themselves to their new conditions, although not without some difficulty); they very rarely encountered food and food rarely came their way!... But we also witnessed scenes where an unfortunate lamb, chamois, deer, cow, hare or horse was carried willy-nilly into the jaws of a bear, lion or wolf.... In chorus they bleated,

mooed and neighed but could not evade their inexorable fate. Incidentally, an animal was carried within a metre of a beast of prey, which in spite of its sincere desire to make the best use of the wild game, was unable to do so. Then, again, a domestic animal sometimes knocked into the back of a beast of prey, bounced off and away from it, thus escaping its claws. When it was possible and necessary we rescued an animal ... for the purpose of eating it ourselves!

Chapter 4

THE GRAVITY HATER

(A Touch of Humour)

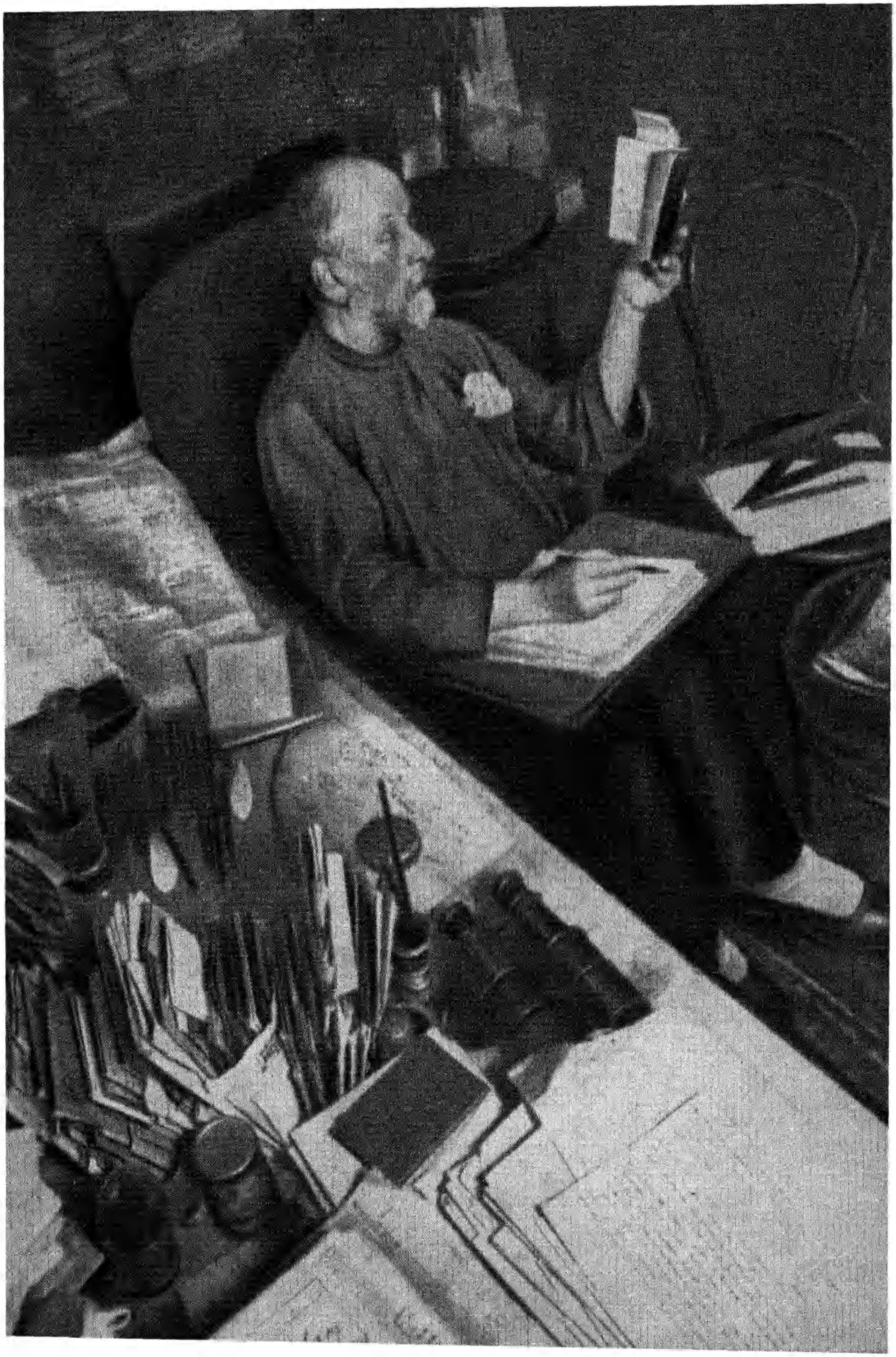
23. One of my friends was a very odd fellow. He hated terrestrial gravity as though it were something living; he hated it not as a harmful phenomenon, but as his personal, bitterest enemy. He delivered threatening, abusive speeches about it and convincingly, so he imagined, set out to prove its entire worthlessness and the bliss that "would come to pass" through its abolition.

"For pity's sake," he cried, "you can't build a house without gravity hindering it with all its might.... Drag up the bricks, haul up the logs.... Why shouldn't I be able to straddle a log and ride it out of the forest?... And all because of this mischievous gravity! It won't let us move fast, comfortably and cheaply.

"Isn't it to gravity that we owe all the frightful expenditure on the railways, which are still very imperfect, insufficient and costly?!

"You can't go down a mine or climb a mountain without difficulties, dangers or expenditures.

"You have to thank gravity," he yelled, "for killing workers by burying them underground, for the bridges and buildings that cave in and bury people under the wreck-



Konstantin Tsiolkovsky in his study (1932)

Konstantin Tsiolkovsky works on the design of his all-metal airship (1933)

age, for drowning people and sinking ships laden with grain and other riches, for smashing people to smithereens when they fall from buildings, and for destroying crops with hail, for preventing the glorious development of the animal and vegetable world, and for countless other vile tricks.

"It forces you to build massive, luxurious homes, to buy upholstered furniture, mattresses, pillows and feather-beds. . . .

"You have to thank gravity," he continued, "for pressing you down to the Earth like worms, for shackling you, and scarcely allowing you to look at the sky and Earth, for the miserable altitude of 10 kilometres, to which man rises with much sacrifice and danger to life, represent, in the heavens, no more than a grain of sand on the peel of an orange.

"Isn't it gravity that limits our portion of space and sunlight?!

"But an environment free from gravity," he would say, with great emotion, "that's the thing! It makes the poor equal to the rich, for it gives both a comfortable carriage with wonderful horses which need no fodder and are tireless. Everyone sits, sleeps and works where he chooses, needing no ground and using fine furniture of comfort quite beyond compare. Houses of any size can be built everywhere, on a hill or mountain, which is a tremendous advantage in many respects: they don't have to be strong and, at the same time, they can serve as airships carrying, inside or outside, as many passengers and as much cargo as space will permit.

"The high speed of such ships, if they are streamlined, will be outstanding. Travelling eternally they will provide their owners with all the blessings and treasures of the Earth, the journey round which having become a mere trifle."

"But that will lead to complete chaos," we tried to argue. "What will become of the seas, the oceans, the air?! How will raindrops fall and how will the fields be

irrigated? Indeed, salt water will flood your house, your garden and vegetable patch. How will you keep it out?"

But there was no stopping the odd fellow; he would not listen to anything and would grow angry at the objections, saying that no one understood him.

Then we would ask him: "But where is there such an environment? And has it anything to do with us? And isn't this 'happy Arcady' merely a figment of your imagination?"

"I have invented no 'happy Arcady', and there is really such an environment on the asteroids," he would reply.

"But there is no air there, no atmosphere," we would say. "Besides, it is too far from us, unless you consider a few hundred million kilometres a short distance."

"To begin with, distance is nothing because it depends on the speed of motion and the convenience of the means of communication. Before Columbus, America was inaccessible, although it was relatively not far away; now it is only 5 to 7 days' travel from Europe. Besides, why do you think that creatures cannot live without visible breathing? Why shouldn't people be able to adapt themselves to such a life in the course of time? According to some naturalists, the atmosphere must, in time, be absorbed by the Earth's crust and together with its elements form a chemical compound, then human beings and animals will have to be content with less and less oxygen, anyway. Must everything perish and not become adapted to the new life?

"Finally, gravity can be done away with on the Earth, too. Don't you know that even now it is being weakened by centrifugal force, and that at the equator gravity, partly because of this, is less than it is at the poles?"

And then he would talk such nonsense that his audience would merely shrug and walk away.

And yet many of his fantasies appealed to me for their scientific and philosophical undercurrent, wealth of images and the train of thoughts they invoked.

He said, for example:

"If we lived at the bottom of the seas under tremendous pressure, and were merely fish that could think, and if we were told that there were organisms living without water and without its pressure, we would cry out: What?... Without water?!.. Without pressure?! For goodness' sake! Then how do they swim? What do they eat? Why, the sun would dry them up! Of course, for sure they would be dried up by the Sun!"

Let us, for the time being, leave aside these arguments, this diversity of fantasies and make use of them sparingly and in their proper place.

Chapter 5

IS IT POSSIBLE TO PRODUCE ON THE EARTH AN ENVIRONMENT WITH A DIFFERENT GRAVITY FROM THAT WHICH THE EARTH NOW HAS!

24. Increasing the gravity in a spinning bowl. It is extremely easy to increase relative gravity in a medium of a known volume.

Imagine an enormous round bowl about 25 metres wide and let it spin like a clay bowl under the hands of the potter who is shaping it. Let us enter this bowl, taking with us a 5-kg weight and a spring balance.

When we stand at the very bottom, in the centre of its rotation, the balance shows 5; but as soon as we move away from the centre the balance appears to be incorrect, and the farther we move away from the vertical axis of rotation the more incorrect is the balance. According to the distance we move away, it shows successively 10.5, 11, 12, 13, 14 pounds; at the same time we also feel somewhat ill at ease, heavy; head, arms and legs feel as though they were full of lead and the heart beats faster. As long as the bowl spins evenly, this phenomenon is invariable.

If the bowl is in the shape of a paraboloid and spins with sufficient but not excessive speed, we can walk freely all round its walls, remaining perpendicular to them, like people walking on the Earth.

At its edges we stand almost on our sides, i.e., in a recumbent position, although we are not lying but standing in relation to our location; it has to be confessed, however, that we are standing with great difficulty, because the gravity is as great as it is on Jupiter.

If the bowl were closed on all sides and were spinning fairly smoothly (for example, rotating like the Earth) we would not notice that it was spinning but would only feel the increased gravity.

Water poured into our spinning vessel is distributed along its curved surface of the vessel.* The terrestrial seas and oceans are limited by a convex surface, whereas here the surface is concave.

The phenomena in the bowl become somewhat complicated when the observer moves rapidly. But if the movements are slow or normal, but the bowl is large, we would not in any way distinguish this artificial gravity from that of the Sun or Jupiter: bodies would fall, the pendulum would swing and the clock would tick in just the same way, liquid would be distributed in the same manner, the same laws of Pascal and Archimedes would apply, etc., etc. We would observe literally the same phenomena that occur many millions of kilometres from us, on other planets with greater gravity. This artificial gravity would produce absolutely the same effect on organisms as

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* But if the shape of the vessel is irregular, it will in no way prevent the liquid from restricting itself to the surface of the paraboloid. Assuming uniform rotation, complete silence all round, absence of shocks, and a vertical axis of rotation, we shall have a splendid reflector or a concave mirror. By using mercury could we not use it like Newton's reflecting telescope? This mirror may be larger but it is inconvenient because of its eternally horizontal position.

does real, natural gravity. Thus, it is known that the main trunk of most plants rises and grows in the direction of gravity. If we covered the interior of our bowl with a layer of fertile soil and planted seeds of cereals, flowers and trees in it, they would all give shoots in different directions along the entire surface of the bowl, but everywhere in the direction of the relative gravity, i.e., normally to the walls of the bowl.

Such experiments have already been made, and confirm what has been said; the vessel with soil and germinating seeds rotated by means of a small water-mill.

I experimented with insects, and calculated that their weight increased 300-fold. Thus they became 15 times as heavy as gold coins of the same volume. In precisely the same way I increased the weight of the cockroach, and even this seemed not to affect it. It evidently follows that the cockroach, and still less other very small insects, would suffer no discomfort at all if transferred, say, to the Sun, assuming, of course, that it was cold there and atmosphere was suitable. It would be interesting to know what amount of increase in gravity has no harmful effect on other, larger creatures, and especially human beings. These experiments are not at all difficult. I increased the gravity of a chicken several fold (I do not remember exactly how much, but I think—fivefold) but this did not kill it.

Here gravity is the result of two factors: the attraction of the Earth and motion; but it is possible by motion alone to produce the purest mathematically identical environment of relative gravity, a phenomenon which will not differ one iota from natural gravity no matter what the conditions.

For this purpose, it is necessary to impart uniformly accelerated and direct motion to the medium in which it is desired to produce artificial gravity. Naturally, in practice this motion can continue for only a few seconds or, at best, minutes.

If bodies fall rapidly to the ground, it is a sign of gravity; if, on the contrary, the bodies are motionless and the ground moves towards them at a uniform speed, we have the phenomenon of apparent gravity which, incidentally, in no way differs from natural gravity.

It is known that the weights in Atwood's machine move at a uniformly accelerated speed. If we make ourselves as small as a fly and alight on these weights, we shall feel during their motion an increase or decrease in our gravity, depending on whether they move upwards or downwards. The heavier one weight, compared with the other, the closer to zero is the seeming gravity on this weight, whereas it becomes almost doubled on the other weight.

25. *Examples of an apparent change or even the complete annihilation of gravity in the given environment.* When you skate or toboggan down a good, ice-covered, fairly steep hill, the direction, as well as the stress of gravity (with respect to the skates or toboggan), are disturbed. The gravity diminishes, while the direction is normal to the surface of the hill. The steeper the hill, the weaker the relative gravity and the more does the body of the skater or tobogganer deviate from the vertical; on the contrary, the gentler the slope, the less does gravity change.

When people ride on the roller-coaster the same thing occurs, only with more variety, i.e., with an increase, a decrease and the total destruction of gravity (in relation to the coaster and the people in it).

Of course, all this lasts only a few seconds, and the passengers, unable to account for the phenomena, merely experience the thrill and have the sinking feeling, which people who like keen sensations find so pleasant.

Gravity changes its direction and stress on all bodies on which uniform or nonuniform curvilinear motion exists. All sorts of swings and roundabouts are places of a seeming change of gravity which makes itself felt in sinking feelings, dizziness, etc.

Somewhere, someone proposed to give the lovers of keen sensations a special thrill. The idea was to put these "thrill-lovers" into a chamber and to have it fall from a high tower straight into a tank of water, where it would gradually lose speed and would then re-emerge into the light of day to the general delight of the public and the lovers of thrills.

But what feeling do these people experience during their fall and swift immersion in water?

Assuming that the chamber falls from a height of 300 metres, i.e., from the Eiffel Tower, we shall find that for a period of almost 8 seconds, before hitting the water, the passengers will be in an environment of seeming absence of gravity. This is because the gravity of the Earth attracts the chamber together with the bodies it contains, owing to which the gravity does not disturb the position of these bodies in relation to each other and in relation to the chamber.

For example, how can a stone fall to the floor of the chamber if the chamber itself is falling at the same speed as the stone?

Furthermore, during the immersion in water the relative gravity in the chamber has a chance to increase to such an extent (depending on the shape of the chamber) that the "lovers of keen sensations" will be flattened out under their own weight like bugs crushed underfoot.

I would propose another method which, the height of the tower being the same, offers twice as much time to observe the space free from gravity and, in addition, a method in which the subsequent increase in gravity occurs fairly uniformly and depends completely on us; this being the reason why under certain conditions this method can be perfectly safe.

The method is as follows: a carriage is placed on the rails which have the form of a propped-up magnet or a horseshoe. The carriage firmly grips the rails on both sides and cannot be derailed. Falling from one end of the rails

the car describes a semicircle at the bottom and rises to the other end where it stops automatically as soon as it loses all its speed.

During the descent to the semicircle (the curve) the relative gravity disappears; on the curve it emerges again, in a greater or lesser degree, depending on the radius of the semicircle, but is approximately constant. During the ascent along the straight or upright rail gravity disappears; it also disappears during the return drop if not retained at the top. Thus the time for observing the seeming absence of gravity is doubled. If the friction of the car against the rails and the resistance of the air are disregarded, the car ought to roll back and forth eternally, like a pendulum. In that case the observers sitting in the car would alternately experience the absence of and the increase in gravity.

The following are the results of calculations in which we disregarded the complicating conditions of friction against the rails and the resistance of the air; nor are they of any importance at low speeds and heights.

Data: the Eiffel Tower—300 metres tall; radius of the curve—15 metres; conclusions: longest time of the gravity-free space—15 seconds; increase in gravity during motion along the curve—40 (a man weighing 60 kg would weigh 2,400 kg or twice the weight of gold of the same volume as the man); time during which it was observed—slightly over 1 second.

With a fourfold increase of the arc radius normal gravity increases only tenfold (600 kg in man) and will continue for 4.5 seconds.

If a drop is 4 times less, the time, during which the seeming absence of gravity is observed, will decrease only twofold (8 seconds), but gravity, with the same arc (15 m) will decrease fourfold and a 60 kg person will weigh 600 kg, while with a radius of 30 m he will weigh 300 kg; in a recumbent position or in water (up to the

neck) man will in all probability tolerate such a weight without ill effects.

With a still lower drop the safety increases more, but the time for observing interesting phenomena is too short.

When a man skating or tobogganing down an icy hill rapidly changes his direction at the foot of the hill, his relative gravity increases, although only for a short time, 10-20-fold or more, depending on the circumstances. It is well known that the man feels none the worse for it.

There are conditions under which even a tremendous increase in gravity proves perfectly harmless to man—for example, immersion in water. It would be extremely interesting to perform such experiments in a spinning bowl (Essay 24).

25. Can the human organism endure weightlessness? A method of protecting the organism from the effects of the dreadful force of gravity. Something similar to the absence of gravity can also be experienced for prolonged periods on the Earth.

Let us imagine a large, well-lighted tank of clear water. On immersion in the water, a man whose mean density equals that of the water loses gravity and the effect of this is balanced by the reciprocal effect of the water. By putting on special spectacles one can see as well in water as in the air if the water is not deep and is clear. It is also possible to use a breathing apparatus. And yet the illusion will be very far from complete. True, the man will be in equilibrium in any part of the liquid; by hooking a small object, he can also give his body any steady direction he chooses, but the resistance of the water is so enormous that the motion imparted to the body is almost immediately lost, unless it is extremely slow and imperceptible to the eye. Since such a position in water is perfectly harmless, it must be assumed that the man will also endure the absence of gravity for any length of time without any ill effects. As a matter of fact, the absence of gravity eliminates the weight of the column of blood and

must therefore increase the blood pressure in the brain. But the same increase also occurs upon immersion of the body in water; almost the same thing occurs in a recumbent position, so that the organism experiences nothing in particular by the elimination of gravity.

The most fragile bodies placed in a liquid of the same density sustain, without breaking, the hardest blows by a vessel or against the vessel as long as the vessel itself remains intact.* And yet under these blows, the relative gravity in the vessel increases, if only briefly, several hundred- or several thousandfold. It is well known that nature places everything that is weak and delicate—embryos, the brain—in liquids, or surrounds them with liquid. Could we not also avail ourselves of this method for a variety of purposes?!

26. The apparent and prolonged elimination of terrestrial gravity is impossible in practice. Let us suggest more examples of weightless environment existing for a longer period of time.

If its mass is very small, an imaginary satellite of the Earth, like the Moon, but as close to our planet as we choose only beyond the limits of its atmosphere, that is, about 300 kilometres distant from the Earth's surface, will offer an example of a weightless environment.

We explained in Essay 16 why, although it is close to the Earth, the bodies lying on it or near it are apparently not affected by gravity.

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* You can personally prove the correctness of the above. Take a glassful of water, a hen's egg and salt. Put the egg in the water and pour salt into the glass until the egg begins to rise from the bottom to the surface of the water. At this point add some water, so that the egg is suspended in equilibrium at any point in the vessel, i.e., so that, being suspended at an average height, it will neither rise to the surface nor drop to the bottom. Now strike the glass against the table as hard as the strength of the glass will permit and you will observe that the egg in the glass will not stir. Without the water the egg naturally breaks immediately even from the slightest blow. I have described these experiments in Volume 4 of the Transactions of the Moscow Society of Amateur Naturalists, 1891.

"So near and yet so far." To be sure, despite the relative proximity of such a satellite, how could we get beyond the terrestrial atmosphere to reach it, even if it actually existed? Or how could we impart to a terrestrial body the speed necessary to develop a centrifugal force overcoming the gravity of the Earth, if this speed must be close to 8 kilometres a second?

If we could build a train which sped along the Earth's equator at the rate of 8 kilometres a second, gravity would be eliminated in the carriages by the centrifugal force; but unfortunately the air will under no circumstances allow motion at such speed.

If we could build a platform belting the Earth at a height beyond the atmosphere, then out there in an absolute vacuum this speed could be attained, but then, practically speaking, the platform itself at a height of 300 kilometres is an absurdity.

If the Earth gradually increased the speed of its rotation, it would at first flatten out along the equator into a pancake and would then break up and form, under favourable conditions, something like Saturn with its system of rings; there would be almost no gravity on these rings.

But such a thing is even less conceivable than fast trains.

What else is there, then? Should we perhaps build high towers or fire cannon balls like those "fired" by Jules Verne?

As we ascend a tower, gravity gradually diminishes; and, if this tower is built in the equator of a planet and therefore rotates rapidly with it, gravity also diminishes not only because of its gradual departure from the centre of the planet but also because of the increase in the centrifugal force which is proportional to this recession. The attraction decreases as the light of a lamp placed in the centre of the Earth decreases as it moves away from it, while the centrifugal force, acting in the opposite direction, increases. Finally, on the Earth gravity is destroyed

at the top of a tower 5.5 Earth's radii tall (34,000 kilometres from the Earth's surface; the Moon is about 11 times as distant).

As such a tower is ascended, the gravity gradually diminishes without changing direction; at an altitude of 34,000 kilometres it vanishes completely, and higher up appears again with a force proportional to the removal from the critical point, but in the opposite direction, so that the climber is turned head towards the Earth which he sees above his head.

Here are a few more calculations of this kind, concerning the planets which differ most from each other.

1. On Mercury and approximately on Mars the critical point is at a distance of 6 radii of the planet or 3 radii of the Earth.

2. On Venus it is about the same as on the Earth.

3. On the Moon it is at a distance of 50 radii of the Moon or 13 radii of the Earth.

4. On Jupiter it is at a distance of 1.25 radii of Jupiter (reckoning from the surface of the planet, as in all these calculations) or 14 radii of the Earth. Incidentally, the new satellite of Jupiter is at a distance of only 0.25 of the radius of the planet.

5. On Saturn the critical point is at a distance of 0.80 of its radius or 6 radii of the Earth. At this distance, or, to be exact, somewhat closer to the planet, Saturn's ring begins.

6. On the Sun its attraction is eliminated by centrifugal force at a distance of 26 radii of the Sun or 2,800 radii of the Earth. The height of such a tower constitutes 0.125 of the total distance from the Earth to the Sun.

There is no need to speak of the possibility of such towers existing on planets, and yet, even in the planetary system, which is just a speck in the space of countless numbers of other such systems, we see something of the kind when contemplating Saturn's ring through the telescope.

If we fired a cannon-ball—a compartment with people, air and food—how long would it all last? Besides, with a cannon even a few kilometres long, so powerful is the relative gravity formed in the barrel when the cannon-ball passes through it that, even before the cannon-ball leaves the barrel, a man in it would be crushed by his own weight, which would be a thousand times greater than his ordinary weight.

Yet, on leaving the dark barrel, always supposing that by some miracle the traveller inside the cannon-ball has remained intact, his weight will immediately disappear and he will find himself close to the Earth, yet apparently outside its influence; it makes no difference whether the speed of the missile is high or low (i.e., gravity is eliminated anyway), but it should be high in order that the missile keeps travelling and does not crash back to the Earth like a ball thrown up in the air. For the cannon-ball to move farther and farther from the Earth eternally and become a satellite of the Sun it requires a speed of 11 kilometres a second; for the cannon-ball to move away eternally from the Sun and become a transient comet it requires a speed of at least 27-30 kilometres a second (with the cannon-ball being fired in the direction of the annual revolution of the Earth).

I suggested a cannon not more than a few kilometres long, but if we build them horizontally several hundred times as long, then relatively speaking the undertaking would not be so inconceivable because the relative gravity in the cannon-ball does not increase very much, and under favourable conditions (immersed in liquid) a man could easily endure it.

Chapter 6

27. The crank's thoughts about the harmfulness of air and the possibility of living in a vacuum; his dreams of a special race of rational beings living without an atmos-

phere. This crank of mine turned out, in addition, to be an air-hater.

"Air impedes rapid motion," he said excitedly, as usual. "Air destroys motion!

"Air in an environment devoid of gravity is a downright nuisance!

"If there were no air I could push off and fly millions of kilometres; but, as it is, first I have to replenish the motion by constantly pushing off, wasting energy in proportion to the distance or time passed; secondly, if the speed of cleaving the air is to be high, the low expenditure of work at low speeds increases extraordinarily rapidly and becomes an unbearable burden."

Thus, a tenfold increase in speed increases 1,000-fold the amount of work per unit of time spent on cleaving the air; a 100-fold increase in speed increases this work 1,000,000-fold. Yet in an absolute vacuum the speed, however high, once acquired by a body is retained by it eternally and requires no expenditure of energy.

True, there are forces, in addition to friction and others that are well known, which decelerate motion—electrical and mechanical induction, for instance. The influence of the Moon produces the tides on the Earth, the phenomenon which decelerates the diurnal rotation of the Earth*; I call this mechanical induction. Ordinarily its influence is entirely unnoticeable.

"You said," he continued, "that the equatorial train can't move at the rate of 8 kilometres a second because of the resistance of the air, and that it was therefore impossible to eliminate the gravity in the carriages of this train."

"I pointed to the resistance of the air," I rejoined, "as being one of the main reasons for the impossibility of attaining such speeds, but this does not mean there are no other obstacles."

* But maybe it is accelerated just as much by the contraction of the Earth due to cooling.

"Wait and let me finish. Just imagine there is no atmosphere on the Earth and our planet is smooth. In that case why shouldn't the train have the speed which destroys gravity by centrifugal force?"

"Once we had imparted such speed to the train," he argued with growing animation and preventing us from interjecting a single word, "the train itself would lose gravity, would no longer press against the ground or touch it and would travel eternally round the Earth, like the Moon does, never tiring and retaining for its passengers the wonderful conditions of an environment devoid of gravity."

"All this is very fine," we would say, "but you're running away with yourself, forgetting that the Earth is not smooth, that it has oceans and an atmosphere, and that no human beings or plants can live without them."

"I don't mean the Earth alone. I mean the planets in general and the living beings which perhaps inhabit them. For example, on the asteroids and the Moon there is no air or water, the surface on them can be made smooth, or at least a road can be levelled out and so impart fast motion to the trains; there the creatures may be adapted to living in a vacuum. Don't we see life existing on the Earth in all kinds of conditions: in water, salt and fresh, in the air, in the soil and on heights, in warmth and in cold, in arid deserts and in the marine depths, under frightful pressure and in the mountains where the pressure is relatively very low. You must agree," he continued, "that even if living beings need oxygen, its extreme rarefaction does not play the decisive role and does not negate life. For example, its solution in rivers is not greater than 1/140 of the density of the atmosphere and yet it suffices to maintain life. But it is not at all difficult to maintain such density and a correspondingly low pressure in thin, closed vessels.

"Let us imagine a glass sphere several metres in diameter equipped with a strong protective steel-wire mesh.

Or let us imagine an incomparably larger steel sphere with a continuous series of holes hermetically sealed by clear, transparent panes of glass.

"Put some soil, plants, oxygen, carbon dioxide, nitrogen and moisture inside, and all the conditions for the existence of animals will be observed.

"This sphere is speeding with all its content through an absolute vacuum without encountering the slightest resistance, like an asteroid, and in rapid motion like the latter, loses relative gravity which cannot therefore break it or crush it by its own force. The only concern is to control the negligible pressure of gases."

"That's too artificial and unstable; it isn't natural."

"Spectacles are also unnatural, yet you wear them. The greater man's progress, the more he replaces the natural by what is artificial."

"But first you must prove that organisms can exist in a vacuum without any of your spheres; you must prove that they live there as freely and naturally as fish in water."

"Certainly. What do they need? Heat! They get that from the Sun, and the intensity of the heat does not make much difference; what's more, it partly depends on the surrounding conditions. For example, when the Sun is in its zenith over the Himalayas, the peaks are closer to the Sun than the foot-hills, and yet the temperature, on the contrary, is lower at the summits than it is at the sea level.

"One and the same body becomes heated to extraordinarily varying degrees, depending on how it is placed in relation to the Sun and what colour it is; here the atmosphere is of no consequence.

"What else do animals need? Motion! That is provided by the same Sun, because the energy of its rays is not small; each square metre of surface, being in a position normal to their direction and at the distance of the Earth, receives 2-3 steam hp, which is equal to the steady work of 20-30 men; if we could make use of 0.5 per cent of this

physical work by transforming it into mechanical work by means of special motors (something that can also be done on the Earth) we would still have more than enough for one anthropoid being; in an environment devoid of gravity even this is superfluous.

"The animals also need oxygen and food for thinking, growth and muscular activity," he said pursuing his line of argument, "oxygen can be formed by the chemical work of the Sun's rays in the body of the animal or in its special organs, just as it is formed in the green parts of the plant from the carbon dioxide of the air.

"The animal's carbon dioxide, instead of dispersing in the atmosphere, will remain in the animal and will serve as the material for forming oxygen and new reserves of carbon.

"As in plants, the chemical activity of the Sun will generally be complex and multifarious and will provide the animals with all they need for life.

"Thus in these wonderful creatures the animal will merge with the plant into a single whole and such a creature can, therefore, be called an animal-plant. As is well known, there is something of this kind in the world of terrestrial organisms.*

"But the digestive, respiratory and other excretions of our imaginary animal-plant are not lost; they are fully reprocessed with the aid of sunlight into food and oxygen which the creature uses again as food, thus completing an eternal cycle and never becoming exhausted.

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* Green grains of chlorophyll have been found in radiolarians—minute, unicellular animals living in very large numbers on the surface of the sea; chlorophyll has also been found in relatively large animals—the hydra, sponge, medusa (bell-shaped), actinia, etc. The role of chlorophyll consists in reprocessing the carbon dioxide excreted by the animals, by means of sunlight, into the oxygen and carbon required for nourishment and respiration. Such a creature can, theoretically, do without external oxygen and external food. Scientists hold that the green of these creatures is an entirely separate organism so that in this case they regard it only as an example of symbiosis.

"There is nothing impossible in this. Do we not see the same thing, only on a larger scale, on the surface of the Earth?! Don't the selfsame materials eternally serve for the vital processes of plants, animals and even man himself?!

"The Sun keeps working, but the material is always the same and never becomes exhausted. Why do you not want to admit on a small scale what already exists on a large one?"

"But we do! Calm down and merely explain how your creatures will manage not to dry up like mummies?"

"That's simple. Their skin is covered with a hyaline layer, rather soft and thin, but absolutely impermeable to gases, liquids and other volatile bodies and therefore safeguarding the animals against all and every material loss.

"These animals have no external apertures in their bodies; the cycle of gases, liquids and dissolved solids—all this takes place inside the animals and not through the external environment. The surface of the body with small wing-like appendages illumined by the Sun serves as a laboratory for producing life and power. If such appendages cannot be burdensome in the environment of gravity, in space devoid of gravity they are imperceptible even with a surface of several thousand square metres."

"I say! And how will they, your animal plants, communicate with each other, exchange ideas without air? For ether does not transmit sound waves."

"Firstly," he said, quite unperturbed, "sound vibrations can be communicated from one creature to another along a conductor, like a wire, and weakening even less because of the distance than when they move through a liquid or gaseous environment. Secondly, do we exchange ideas only by means of sound, voice? What about books and letters? Something like that, but much more perfect and natural, serves them for communicating with one another. On one of the visible parts of the body, through its transparent coating, as in the camera obscura, a series of living pic-

tures appear, follow the thoughts of the creature and give them precise expression. It depends on an influx of variously coloured subcutaneous fluids into extremely thin vessels, the fluids painting a series of rapidly changing and easily understandable pictures."

Chapter 7

IN THE ASTEROID BELT

(From the Odd Fellow's Fantastic Stories)

28. *How I found myself on an asteroid.* In addition to the eight large planets with their satellites and asteroids which are also quite large and which move between the orbits of Mars and Jupiter, a mass of small planets, so small that they cannot be seen through a telescope, also revolve round the Sun.

The certainty that they exist arises out of the following: no one doubts the existence of numerous stones (aerolites) which, like the planets, revolve round the Sun; some of them brush up against the Earth and fall on to it; others, presumably losing their speed because of the resistance of the ether and excited by the motion of induction, fall on to the Sun giving a little support to its luminosity. If there are large and small heavenly bodies, why should there not be intermediate ones?*

I have been on asteroids and still smaller planets and have seen life on them. Oh, each is a marvellous country! <. . .> There were wise creatures who <. . .> surrounded me with every comfort, supplied me with an arti-

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* When our cranky fellow expressed this idea the planetesimals of up to 6 kilometres in diameter had not yet been discovered. Thus he forecast this discovery. When our instruments and methods are perfected we shall no doubt discover still smaller planets—real heavenly Lilliputians.

ficial atmosphere, enclosed in a spherical, partially hyaline contrivance in which there were plants with lovely ripening fruit that satisfied both hunger and thirst excellently.

But that was not all; when I wanted to see how they lived, they covered me up closely without affecting the shape of my body or interfering with my freedom of motion; the covering was a rather thin membrane which protected my body against the dangerous absence of atmospheric pressure; they supplied me with oxygen-containing vessels and various other apparatuses which were connected with my body and for some time took the place of air and food. Owing to the almost total absence of gravity these apparatuses, of course, would not have been a burden to me even if they had been 1,000 times as massive.

Thus I used to leave my abode and see everything.

To them it made no difference whether they lived in an atmosphere or without it, because gases and foreign bodies in general could not penetrate their skin; the layer of atmosphere only retarded to some extent the process of their nutrition through the Sun's rays.

I shall omit the infinitely complex, vast and multiform structures, the mysterious deeds and the mass of phenomena which I could not divine, and shall only describe the things that strike the eye and can be grasped by our human mind.

When I grew accustomed to them and learned their visual language (they supplied me with a special mechanism which gave a "pictorial" expression of my thoughts) I conversed a great deal with them.

I shall not speak about their figures, because ideas about beauty are extremely subjective even among one race of bipeds; still, I can say that even to me, a human being, their figures seemed highly elegant.

Is there any need to remind you that from the asteroids the Sun appears very small and emits 3, 4, 5 and even 20 times as little light and heat as it does on the Earth? The asteroids closer to Mars receive one-third of what we

get, and the farther they are from it, the less light and heat they get from the Sun. On Jupiter the power of the luminary decreases about 25 times and the Sun looks like a voltaic arc, almost a star.*

I therefore required some protection against cold, the amount depending on where I happened to be at the time. The inhabitants of these places, too far removed from the Sun, were cold-blooded, like our fishes and insects, and were made of substances which do not freeze easily.

29. My conversation with the natives. "Where are you from?" I once asked them.

"We are migrants from other large planets."

"But how did you get here and how do you live in a vacuum, if your bodies were adapted to life in an atmosphere?"

"I can't explain to you how we even got here, because it is too complicated; as to the atmosphere, our bodies were gradually transformed and became adapted to life in a vacuum, just as your aquatic animals were gradually transformed into land animals, and the nonflying into flying animals. Generally speaking, the aquatic animals were the first to appear on the planets, then came the animals that lived in the air and, finally, those which lived in a vacuum."

"<. . .> Would you kindly tell me what you feed on?"

"<. . .> We feed and develop like plants—through the action of the Sun's rays."

"<. . .> But I still don't understand. Plants feed on the nutrient fluids of the Earth and the gases of the air, which the energy of the Sun's rays transforms into plant tissue."

"You see the green appendages of our bodies that look like beautiful emerald wings? They contain grains of chlorophyll, like that which gives leaves their characteristic colour; some of your animals also have such grains

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* But the intensity of this light is also at least 20,000 times as great as our lunar light under the most favourable conditions.

in their bodies. Because of their hyaloid membrane the wings allow nothing to escape, but freely absorb the Sun's rays. These rays break up the carbon dioxide dissolved in the fluids which flow through our wings, like the blood of your body, and perform thousands of other chemical functions which produce various gases, liquids and solids. All of these immediately enter into a relation, partly physical, partly chemical with the other constituents of the juices and form liquids, i.e., enrich the juices with new substances. Thus enriched, the juices constantly supply our bodies with all they require for their nourishment: oxygen in a weak chemical compound, hydrocarbons and nitrogenous substances. The Sun does something like this in your plants <. . .>."

"But kindly tell me how, the surface of your wings being so small, you obtain so much from it, even without fertilisers, for in order to subsist on the Earth, a man needs several hectares of land, a thousand times more, in fact?"

"Let me tell you how," one of the natives said. "In a vacuum, the energy of the Sun's rays is extraordinarily great; besides, we transform a much greater part of it (1/6th) into potential chemical energy, than you do on your planet through your plants, and it quite suffices to maintain our vital processes. You must know, indeed, that a square metre of surface illumined by the rays of the Sun, which are normal to it, produces work equal to almost 3 hp. But we are farther from the Sun and receive 3-4 times as little energy from it. Thus with a total wing surface of about 3-4 square metres we have work in one day equal to the potential energy of 5 kilograms of purest carbon, assuming that during the production of the energy it burns in oxygen. The greater part (5/6th) of this energy heats our bodies and the rest (1/6th) is used up as food. The energy of this food corresponds to almost 1 kilogram of carbon. One would require very much food in its usual form to obtain that much energy from it (almost 4 kilo-

grams of bread or 5 kilograms of meat*). It follows from this that we cannot be hungry."

"What? Do you really never experience the unpleasant sensations of hunger, thirst or indigestion?"

"Never! We have a regulator which indicates when we should turn our wings to the Sun <...>. When there is a danger of exhaustion the regulator carefully points it out. Incidentally, there are no clouds in our environment, and we get our nourishment unimpeded."

"So that's what your beautiful wings are for! They serve as your orchard, vegetable garden, field, cattle-yard and so on, since they supply all you need for your table. At first I thought you used them for flying."

"We can fly without wings; in a vacuum wings are useless for your ordinary flying. Can your flies fly when the air is pumped out of the bell-jar?"

30. More conversations. These creatures with their properties surprised me; they neither ate nor drank <...>, and did not seem to ail or die! And yet they had a bodily membrane! Here are some more of our arguments concerning these things.

"Do you ever ail?" I once asked.

"Very rarely; one in a thousand may fall ill in the course of a thousand years."

"Do you live so long?"

"Like your plants we have a life of indefinite duration. There are very rare cases of death due to some unfavourable course of events; death from disease is even rarer."

"But how do you account for such longevity, almost immortality?"

"Some of your trees live for thousands of years despite the fact that they are continuously in the grip by disease, crawling with parasites, felled by winds and gravity, and the stronger they are, the older and more massive they become. We are insured against all this and

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* Lebon's Physiology. *Nutrition and Its Methods.*

against much more. . . . Why should we not live long? We owe our longevity to the cleanliness of our bodies which carry no infectious agents—all the cocci, bacilli and fungi which teem in your wretched bodies and produce a constant threat of destruction; we owe our longevity to the complete isolation of our bodies from harmful elements, thanks to the absolute vacuum that surrounds us and the impermeability of our skin; we owe our longevity to the wonderful structure of our bodies possessing organs of which you, inhabitants of the Earth, have no idea whatever. We have special life regulators which prevent the body from growing old and weak and changing in any way that could be detrimental to the body.

"You have already gained some insight into certain principles of the causes of death. Your experiments with generations of infusoria* have shown that reproduction of budding (i.e., successive division of one infusorian into two individuals) increasingly exhausts their numerous progeny. In just this way the cells of the terrestrial body become exhausted: at first there is an <. . .> increase in its volume—the body grows; then the rate of growth becomes increasingly retarded because, although the number of cells increases, their volume continually decreases due to degeneration; there comes a moment when the bodily volume ceases to increase. This would be no misfortune if the quality of the cells (and the various body tissues composed of them) did not deteriorate with each new generation of cells; old age sets in, the body grows thin, fat takes the place of useful tissues, the walls of the vessels, through which the fluids of the body circulate, grow weak and burst under the pressure of the blood in different parts, producing various diseases and death. This is natural, "lucky" death—from old age.

"With us, the cells have an opportunity of forming connections with other cells and reproducing by budding

* Probably colonies of stylonichias.

<...>. This is the merging of two cells into one with the result that the weakened cells are rejuvenated, becoming young and strong <...>; the regulators do not allow them to grow old, nor do they allow them to increase in size beyond a certain limit; their total volume does not change because the amount of material of each individual cell is invariable.

"Yes," the lucky creatures said, "we see that you are ceasing to understand us. We shall try to explain to you, from another point of view, the possibility of extraordinary longevity and even physical immortality. Look at your mankind as a single whole. Is it not immortal in mass? Does this whole die? Or if it dies, are there any definite limits to its longevity?! Who can tell how many thousands or millions of years it will live?

"Think of mankind as a single being, as one of us, and make a comparison; the resemblance will be striking: your people are the different cells of one of our bodies; your instincts, your love and, very likely, your reason are the regulators which support the existence of the whole and do not allow it to grow old and die; if we take your entire organic world with its atmosphere and soil for comparison, the resemblance will be still more amazing: is it not true that you live by the same amount of substance, belonging to your planet, as each of our bodies does? In the final analysis is it not the Sun that feeds you as it feeds us? Is any water, any food supplied to this great (although pitiable) organic body from outside, from another world (say, from another planet)? Perhaps you are given servants, money, or special air? You are given nothing, and yet there is enough of everything, and there cannot fail to be enough as long as the Sun shines and as long as the size of the "great body" does not increase excessively at the expense of inorganic matter. And you can easily picture to yourself the regulators which prevent that excessive growth <...>.

"Our body represents in miniature the organic life of

the Earth," the natives said <. . .>. "You, people, will also be happy, and your generations will not become extinct if you are reasonable."

"That's true, mankind does not die but lives like one of your marvellous beings; it is immortal," I observed. "But you show me an example of individual indefinite extension of life on the Earth."

"I can do that," one of them interrupted. "You have infusoria. The life of each of them consists in its separating from itself similar creatures, one after another, in consequence of which (maybe not from this, but the details would lead us too far) it weakens, degenerates, diminishes and within a few hundred births grows so small that it changes beyond recognition; it begins to die! But another, suitable individual approaches this dying one, merges with it into a single whole and after this—oh, miracle!—it is rejuvenated, resurrected, begins to grow rapidly, reaches the normal size, reproduces again, etc."

"Yes, yes. I read something about it,"* but you probably know better than we do <. . .>."

"Are there many of you?" I asked with interest.

"The solar system, i.e., the Sun itself, can theoretically support the energy of life of 3×10^{23} beings like ours and this number is 15×10^{13} as great as the number of inhabitants on your Earth, assuming it to be 2,000 millions."

"Look here!" I rudely interrupted. "How do you know all these details about the Earth? You have surprised me more than once on this score!"

"Well, here I am talking with you. . . . What makes you think we have never talked with other people like you from the Earth? Moreover, if you had ever seen our telescopes, our astronomical apparatus. . . ."

"I understand. You say—so many times greater than

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* Maupas and Delfeb. The former performed experiments with a colony of stylonichias, the latter advanced an explanation of the results obtained by the former.

the population of the Earth.... But it comes to a colossal number!! How can one grasp it in a more perceptible way?"

"Like this. Imagine a box 25 m high filled with poppy seeds, each of which is not more than 1 m in diameter. Imagine that each of these seeds is a terrestrial sphere with all its rational inhabitants; this will give you a clear idea of the number of beings the Sun can feed. As a matter of fact it feeds about 1,000 times less, but not because it cannot feed any more. This real population, according to our arbitrary terminology, will be expressed in a box 5 cu m filled with poppy seeds.

"There are very few of us, belonging to the group of planetoids that travel between the orbits of Mars and Jupiter, just a handful of poppy seeds," the asteroid inhabitant continued. "And don't forget that each seed is an Earth with all its inhabitants."

"I beg your pardon, but I don't agree that there are so few of you. I even fail to understand how there is enough room for you all. The surface of the asteroids known to us is positively negligible."

"We don't need any planet surface; we are satisfied with the world space, sunlight and the material which we find in abundance by digging and breaking up the asteroids."

. . . .

31. The planet from which one can escape by one good leap. We are on an asteroid which is invisible from the Earth even through the finest telescopes because its diameter is not more than 6 kilometres.* The gravity here is so low that it is enough to make a small effort and take

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* These planetoids are observable with extraordinary difficulty only through the most gigantic telescopes. They are best discovered by means of photography. Thus, the discovery of the planetoids Agatha, Philahoris and Erigona has been confirmed beyond all doubt. The first of these has a diameter of not more than 6-7 kilometres.

a long leap to recede from it eternally, never to approach it again. We free ourselves from its gravitation by one good jump which would only raise us about 1.25 metres from the surface of the Earth.

Only the Sun will swerve us from our straight course and make us revolve round itself like a regular planet; owing to this we may, within a fairly long space of time, again come close to the asteroid we left behind, receding from it along a circle and overtaking it from behind.

Please, don't think of our asteroid as being very small: it has a circumference of about 17.5 kilometres, a surface of almost 10,000 hectares, a volume of 92 cubic kilometres and a mass 6,000 times as great as that of the whole<. . .>Earth.

The relative surface of this asteroid is truly diminutive; it can accommodate not more than 3,000* terrestrial inhabitants with their wasteful economy <. . .>.

Here gravitation is 2,250 times as weak as it is at the surface of the Earth. This means that here you can carry 2,250 poods as easily as you do 1 pood on the Earth; you do not feel the weight of your own body because you are pressed to the ground with a force of only some 30 grams (in terrestrial figures); a propped massive pig-iron body about 2 sq m produces practically the same pressure here as a basketful of bread does on the Earth; the weight of a barrel of water produces the impression a glass of wine does on the Earth, a full-grown man on your shoulders feels like a doll weighing 30 grams and 2,250 men like one man on the Earth, even less, because on the Earth you also feel the burdensome weight of your own body, something you don't feel here.

You stand upright on the surface of an asteroid, as you do on the Earth but the slightest movement you make sends you up in the air like a bit of fluff. The effort required to jump on a terrestrial threshold would carry you

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* The planet is farther from the Sun than is the Earth, and the energy of the Sun's rays is therefore 3 times as low.

here to a height of about 250 metres, or a little below that of the Eiffel Tower. Gravity is so negligible here that it would take you 22 seconds, almost half a minute, to fall from a height of 1 metre.

If you deliberately lean over in order to drop to the ground like a felled tree, you will wait several minutes for this pleasure to come to an end and, of course, will feel no impact from the fall. If you draw up your legs in order to sit down, your legs will hang in space for 10 seconds without any support—long enough to light a cigarette (a pity that the absence of air will not allow you to do it!). If, while lying down, you stir, stretch, sneeze or yawn, you immediately rise a few metres into the air, just like a feather caught in a light breeze which is carried some distance and dropped again. You can stand and lie on sharp stones, you will not be cut or get cramp. If you are thoughtless and spring up suddenly from the grass, as you might (on the Earth) in order to greet an approaching lady, you will be carried several hundred metres into space leaving the poor (even if only imaginary) lady deeply perplexed. You rise for about 3 minutes, and it takes you as long to land at some spot about 300 metres distant away from the ill-starred person.

Don't throw small things about because they fly away forever; nor is it difficult to chuck 20-kilogram rocks about, so that they become aerolites and disappear forever.

Here a terrestrial seconds pendulum, about one metre long, swung 47 times more slowly, and the clock, instead of showing that 1 hour 34 minutes had passed, showed only 2 minutes, time appearing to move 47 times more slowly. Our seconds pendulum is so short (less than 0.5 mm) that it is invisible. Watches keep exact time (i.e., their movement hardly depends on gravity at all).

It is very inconvenient to run or even walk on our planet. At the slightest attempt to do so you fly upwards. Incidentally, what you can do is run with giant steps,

covering several metres at a step, but you must step lightly; the moment you step the slightest bit heavily you begin to tumble about in space and to take the next step using head, arms, sides—anything, but not your feet. It's inconvenient, very inconvenient, just try it yourself.

If you want to travel or, rather, fly round the planet along the different meridians and examine its surface, it is best to do so like this: push off with your feet from some rock or projection of the planet, but do it lying down and in a horizontal direction. Then you will fly, or swim like a fish in water—using side-stroke, breast-stroke or on your back. If you push off gently, you will fly a few hundred metres and then approach the ground again slightly scraping it as you move along; here you again push off horizontally from some jut on the ground, repeating the operation 5-10 times until you no longer contact the ground at all; this will mean that the centrifugal force has overcome the planet's gravity. You become its satellite, its moon, and cease to feel the influence of gravity; you are in an environment of a seeming absence of gravity.

Don't imagine you need great speed! One single horizontal leap, needing about half the effort it takes to move completely away from the planet; this leap is therefore equal to a terrestrial high jump of about 5/8 metre. And it is best immediately to acquire the necessary speed (3.6 m per second) by pushing off mightily, as you push off with your feet from the side of a terrestrial swimming-pool.

It will be observed that during any kind of jump or flight (even on the Earth, not considering the air) you are also in an environment of apparent absence of gravity until you touch the ground, just as you are when travelling round the planet. The journey is made without the slightest effort (except the momentary effort, i.e., the jump for 1 hr 24 min at the rate of 3.6 m per second). You must not move any faster of you will recede from the planet,

and at a speed 50 per cent greater than that mentioned (5 m per second, or about 18 km per hour), you will move away, never to return.

If the planet were rotating, the phenomena described would become more complicated.

Although no effort is required to make such a round-the-planet trip, even if you travel for trillions of kilometres, the only drawback is the low speed (about 18 km per hour). True, by arranging the train to travel upside down, as though reflected in a plate-glass ceiling, we could travel at any speed because the centrifugal force will be checked by the rails. By moving 47 times as fast (550 km an hour) such a train gives rise to a centrifugal force equal, but inverse to terrestrial gravity. The passenger "falls", so to speak, "to the ground from the clouds"; when moving 2.5 times as slowly, the gravity is the same as on the Moon. The appearance of gravity naturally increases the friction and makes it more difficult for the train to move.

The many millions who populate the planet live on it only part of the time; most of them, in pursuit of light and room for themselves, form—with their machines, apparatus and structures—a moving swarm around it shaped like the ring around Saturn, only relatively larger. This living ring is located in a plane perpendicular to the direction of the rays of sunlight and is therefore never deprived of its life-giving force; as the planet revolves round the Sun, the motion of the ring changes artificially, so that its "face" continues to "look" at the luminary; the speeds of the elements of the ring are so negligible that the direction of its plane may be changed not merely once a year, but even 100 times a day.

The diameter of the ring is 10 times as big as that of the planet, and for this reason the inhabitants of the former receive 100 times as much solar energy as do the inhabitants of the planet proper. Thus, the inhabitants of the ring number some 800 million individuals.

I visited their ring, flying from one part of it to another and pushing off higher and higher. It always seemed to me that the planet was rotating and we were standing still or moving only when we wanted to.

The parts of the ring moved more slowly the farther away from the planet they were; on the outskirts the speed did not exceed 3.5 km/hr (1.12 m/sec), whereas down below, at the actual surface of the planet, it was 3.33 times faster (3.6 m/sec).

I travelled together with my house and all my house furnishings, as built for me by the inhabitants of the asteroid. I was thus able, whenever I wanted, to enjoy the atmosphere and everything I was accustomed to. As soon as I grew tired of my customary way of living, I donned my "skin" and attached all the equipment I needed for living in a vacuum and wandered about in it, quite imperturbed.

32. An asteroid with a diameter ten times greater. Here is an asteroid with a diameter of 56 kilometres,* a circumference of 176 kilometres and a surface of 9,856 square kilometres. Since this planet is in the proximity of the one described above, it uses the same energy of the Sun's rays but can provide subsistence, on the basis of its surface, to about 800 million inhabitants. Its volume is 1,000 times as large as that of the former planet. Whatever you say, it's quite a planet. A jump no longer raises

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* Some asteroids are smaller, others larger. There are about 220 of the former and close to 130 of the latter. The following are the diameters of some asteroids in kilometres, assuming that they are spherical: Agatha—7, Hestia—25, Atalanta—30, Virginia—32, Leucotea—37, Themis—52, Polymnia, Thocea, Parthenopa, Pomona—about 60 each, Euterpa, Lutecia, Thalia, Proserpina—about 67 each, etc.; then comes a series of small planets showing a steady increase in size. Judging by the steady increase in size of this series, it must be assumed that it shows an equally steady decrease down to the asteroids that are invisible because they are so small. Their masses are not known at all; their shape is very irregular, which allows not only theoretical gravitation but shows that gravitation is most likely because of the extraordinary variability of their brightness or of the sunlight they reflect.

you high in the air—only about 281 metres. Of course, it is not difficult to jump over a belfry or a river. But gravity makes itself felt; terrestrially speaking, your body now weighs about 400 grams; an 800-litre barrel is no longer as light as a glass of wine, but like five litres, and a bucket of water presses with the force of about 50 grams.

It is quite a size! And it is more convenient to run on it than on the other one. Only don't hurry; if you do, you will begin tumbling about.

A stone thrown with a speed of 50 m/sec leaves the planet forever; on the Earth a stone with this vertical speed will go up to about 125 metres; that is why not only bullets and cannon-balls, but even an arrow shot from a toy bow leaves the planet for good. A stone thrown from a sling or by any other simple method easily achieves the speed necessary to escape the planet.

A train developing a speed of 36 m/sec (126 km/hr) loses its weight through the centrifugal force; on the planet this is no speed at all on a good road. Indeed, there is no air, the gravity is 225 times less than on the Earth, and so the friction of all kinds is as many times less. Moreover, with this speed of 120 km/hr sometimes developed by terrestrial locomotives, gravity and, it follows, friction disappear altogether; the train soars and speeds away eternally without any expenditure of power; whereas it is easy for the train to run in the beginning, it becomes even easier later on, because with the increase in speed its small weight diminishes still more, until it reaches zero.

On this planet you could go cycling by adapting the bicycle a little to the low gravity, provided the road were good and smooth. But a little extra effort, and the bicycle would leave the planet and would take you cycling through space.

The inhabitants of the small planets have special methods and devices for accelerating, braking and preventing tumbling.

Round this planet, as round the smaller one, a living ring rotates and receives enough energy from the Sun to support the existence of 20,000 million inhabitants. The population of the ring is twenty-five times, while its surface only six times, that of the planet. The plane of the ring as well always "faces" the Sun, and its elements change their motion as they revolve round the luminary. The diameter of the disk is about 5 times as large as that of the planet. Its inhabitants maintain constant contact with those of the planet in the following way.

All round one of the meridians of the planet there is a smooth road and on the road a moving belt circling the entire planet. This belt is a long annular platform on numerous wheels. By means of solar motors it moves steadily in a continuous strip round the planet at the rate of 4 m/sec. On this platform another, similar but lighter, platform moves by the same method. On the second platform there is a third, and so on. Altogether there are 9 of these platforms. Thus the last annular platform moves at the rate of 36 m/sec, at which speed it loses its gravity. There is no reason whatever to be surprised that such multi-tiered trains are possible; their total weight is 45 times less than one of them (of an average mass) placed on the Earth.

The system described is good for the inhabitants in that it always ensures convenient communication between the ring (or disk) and the planet. If, for example, I wish to make my way to the ring and lose my gravity there, I stand on the planet near the first platform, as you would do, if you wanted to hop on a moving tram. Here they have a contraption to make the whole business easy. But you can manage without it: just run alongside the platform until you catch up with it; it is not difficult to run on a small planet at the rate of 4 m/sec, or 14.4 km/hr (it is possible to run at that speed on the Earth, too); after this preliminary run you will jump without pushing off on to the first platform, and from this, in the same way, on to

the second and, finally, you will find yourself on the last one, where you will be rid of gravity.

33. *The asteroid with a diameter ten times greater still.* It has a diameter of 560 kilometres,* i.e., one-sixth that of the Moon. As you see, this is already quite a good-sized planet. Gravity on this planet is 22.5 times lower than it is on the Earth. A man can jump only about 20 metres, i.e., he can jump over a tall birch-tree, a five-storied house, a 20 m wide ditch or river. A 65 kg person weighs here as much as a 3 kg suckling pig weighs on the Earth. A man of average strength, without any effort, can carry on his shoulders, head or in his arms, wherever most convenient, a crowd of 22 people like himself. The strength of materials in relation to the force of gravity is very great here, too. For example, a person can sit on a swing supported by strings slightly thicker than ordinary terrestrial sewing thread. Buildings of similar construction as those on the Earth are 22 times as tall. On your Earth a tower is 300 metres tall, whereas here it could be 6.6 kilometres tall. A stone cannot be thrown by hand so that it flies away into infinity or revolves round the planet like a satellite. But cannon-balls fly away altogether, while bullets, losing their gravity, revolve round the planet without falling on it.

To destroy the attraction of centrifugal force, a train must travel at the rate of 360 metres a second, or 1,280 kilometres an hour.

The question is: Is it possible to attain a speed which is about 10 times as fast as that of the fast terrestrial locomotives?

Air is the main obstacle to fast motion; but there are

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* The asteroids known to me are smaller, namely: Vesta—406 km, Ceres—367 km, Pallas—225 km, Eunomia—187 km, Juno—172 km, etc. How did our cranky friend ever get to a 600-km planet which, in addition, had a ring greatly exceeding it? Was he not perhaps confusing our Sun with some other sun? Astronomers could never have overlooked such an asteroid in our planetary system.

no gases here. The gravity is 22 times as low and friction as many times less; speed can therefore be at least 5 times as great, i.e., 640 kilometres an hour. At this speed the centrifugal force will constitute only one-fourth of the force of gravity and will therefore not destroy it. Still the decrease in gravity will somewhat increase the speed of the train, but it is doubtful whether the speed will reach the appropriate degree.

Incidentally, the inhabitants of the asteroid attain the speed they need by the extraordinarily easy methods I have already described: by means of many-storied perpetual-motion circuit trains driven by solar motors.

I shall describe these motors in a moment. But first of all, allow me to observe that the inhabitants of the asteroid have achieved great success in the production of uncommonly strong metal vessels which are absolutely closed but capable of changing their volume; for example, like bellows or a concertina.

Now imagine that a vessel, permanently filled with the vapours of some appropriate liquid, has one half black, which is warmed immediately by the Sun, and the other—shiny and silvery. When the black side of the vessel is exposed to the Sun, the temperature and resiliency of the vapours reach their highest magnitude, and when the light half faces the Sun—their lowest. Hence it is clear that, if the vessel rotates (which it can do by inertia), and turns its dark and shiny halves alternately towards the Sun, the walls of the vessel begin to draw closer to each other and then away from each other with a known power, which the natives utilise by means of simple devices. Thus they convert one-third of the solar energy into mechanical energy. This is the simplest possible system, but they also have many more systems, which I do not undertake to describe.

When use is made of a square metre of the Sun's surface at a distance twice as great as that from the Earth to the Sun (as in the case of our miniature planet) work equal to

1/3 hp, i.e., the work performed by three good workers, is obtained.

Working eternally, everywhere and at every altitude, such motors need nothing but the Sun. The inhabitants of the asteroids have them everywhere, in every possible design and for every possible use; they trail after the natives like obedient animals, always offering their services and never tiring.

It is these motors that set the many-storied trains into proper motion.

The number of trains or stories is not great—about 10, but the difference in their speeds is much greater than with the preceding asteroid, 36 metres, in fact. It is very difficult to pass from one train to another without the special devices they have there. Here is one of them. On each train and on the planet itself is an additional railway track with light carriages at different places. Before it is coupled, each carriage either stands still or moves together with the railway track. But it is enough to create slight friction between the truck and the side of the moving train, and it, too, begins to move at the same speed with the latter. Thus, I get into the first carriage and push it against the first train to create friction; within a few minutes I am speeding along with it at the rate of 128 km/hr. From the carriage I pass on to the train and uncouple it from the train, causing it to roll on for a while until it comes to a standstill. From the first train I easily climb in to the next relatively motionless carriage, connect it by friction (through pressure) with the other train, acquire this train's double speed, and in this way rise higher and higher, gathering speed until, in the final train, it becomes equal to the gravity itself.

Then I proceed unimpeded to any part of the ring, at a height of thousands of kilometres, as in an environment devoid of gravity.

All the trains (while in motion) weigh only one-fourth of what one of them would weigh if placed on the Earth.

*34. On the rings of the asteroids.** I shall now describe what I experienced many times on the ring and have not yet passed on to you; this is a more exact description of phenomena in an environment of seeming absence of gravity, I observed these phenomena in great detail for the first time on the rings.

I was in a magnificent palace surrounded by my distinguished friends who suggested I take part in various experiments. They placed me in the middle of the hall in a perfectly motionless position. Do not imagine that this is easy; on the contrary, it is as difficult as balancing a chair on two legs or a stick on its sharpened tip. They took a lot of trouble and used all sorts of cunning methods before they got me into a state of complete physical calm. I don't remember ever before being so absolutely motionless in an environment devoid of gravity. Usually I was always crawling off somewhere, and if I was brought to a halt by some obstacle, I rebounded like a rubber ball and then continued moving in some other direction; and if I was attached to something, though movement became restricted, it was evidently unavoidable; I bobbed about like an angler's float. And so, after getting me into a state of equilibrium they asked me to approach them. I started vigorously moving my legs and swinging my arms but got no closer to the goal. This made me angry and for some moments I alternated between anger and despair, but never advanced an inch. Finally, seeing the futility

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* On Pallas and Ceres Schröter observed atmospheres of enormous height, which were three times in excess of the diameters of the planets. Could he not, perhaps, have been seeing the rings of the asteroids composed of numerous small parts with intervals which therefore appeared to be semitransparent, like liquids or the spokes of a rapidly revolving wheel?! It seems the diameter of this ring is 7 times that of the diameter of the planet; these dimensions are not far from the relative sizes of the rings described by our "wonder worker". And perhaps the asteroids themselves are the disks inhabited by the beings mentioned by our story-teller and formed by them artificially. For the densities and masses of the planetoids are not known to astronomers.

of my efforts, I relaxed my limbs and refused to continue the experiment.

My terrestrial friends would certainly have scoffed at my situation, have tormented me for an hour or two by disappearing and leaving me to the mercy of fate; but here I was surrounded by beings of another kind; they immediately extricated me from my unfortunate situation by suggesting another experiment.

"Throw something to us," they said, "the stick you're holding will do."

I immediately threw the stick and observed that my position in the centre of the hall became disturbed, one wall of the hall drawing closer to me; I had moved in the opposite direction to that of the stick and in a moment came up against the wall with a gentle bump.

On another occasion, and under the same conditions, I was asked to stand upside down; of course, in an environment devoid of gravity there is no up or down and every direction, physiologically speaking, is absolutely the same, so that I use these expressions merely to save time and to make myself clear.

Much as I tried to take some other direction, it was useless, and when I calmed down and assumed the former, most restful posture, my face still looked in the same direction. All my efforts proved futile, and yet I could freely move all my limbs, in fact, just as on the Earth. I curled up in a ball, sat down Turkish-fashion (not in a seat, of course) crossed my arms on my chest or moved them in any direction, bent my head up, down, and to the sides; in a word, my body and limbs could assume any position I chose, but as soon as I adopted the ordinary posture, I found I had neither moved nor turned in the slightest.

Yet it was all very simple.

If you want to turn round, take off your hat and make it spin about its imaginary axis, parallel to which you, too, want to turn; keep your eye on the hat and don't let it

get away; the moment it seems to be making off, pull it in closer and make it spin again. And so, you'll find that as soon as your hat begins spinning, you are turning, too, but in the opposite direction. When you have turned as much as you wanted to, stop the hat; you, too, will immediately stop and will be facing in the opposite direction* without having made any effort.

Thus you can turn about the longitudinal axis of the body and about the transverse axis (perpendicular to the longitudinal axis), i.e., you can spin like a top, swing yourself like an acrobat on a trapeze or move sideways like a bug on an entomologist's pin.

The greater the mass of a body, the more losely packed and voluminous it is, the more difficult it is to make it rotate, and thus you will spin faster and the body—more slowly (the ratio of angular velocities equals the ratio of the moments of the bodies' inertia).

When pushed away, the speed of the repulsed body is greater, the smaller its mass, and vice versa. When the masses, that of you and of the repulsed body, are equal,both fly off at the same speed, only in opposite directions. There are many different laws involved here, and our terrestrial mechanics know them all in detail.

The motion of a body is for the most part complex, i.e., the body rotates round the so-called free axis and at the same time moves forward so that the axis is in direct and uniform motion. The slightest effort is enough to impart speed, if there is some support, even as tiny and unstable as a falling raindrop. But if there is no support only

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* Pick up a cat and hold it horizontally on its back, paws up. When the cat has calmed down, quickly withdraw your hands so that it drops unexpectedly. You will see the cat make a rapid half-turn in the air and land on its feet. What happens to make the cat turn *without support*? The whole point is that actually *the cat has support*, but it is invisible because it is inside the animal. Its support is the animal's abdominal organs with their contents; if necessary, they can twist sharply in any direction by means of the internal muscles.

an outside force can impart speed to you. And once you have speed, you cannot change it without some support. Thus, sometimes I would fly within a metre of the object I needed, but could not get hold of it because, having no support, I was unable to turn sideways.

35. How terrestrial gravity was arranged for me on the ring; various experiments and observations. The kindness, forethought and tender solicitude of the natives towards me made my sojourn among them definitely pleasant. Once, while I was on the ring, they suggested I make use not only of the terrestrial surroundings, which I had earlier enjoyed there whenever I wanted, but also of terrestrial gravity.

An enormous hollow metal sphere, full of air, light and plants which regenerated the atmosphere I polluted by my breathing and supplied me with all kinds of most delicious fruits (unknown to you terrestrial inhabitants) was at my service whenever I wished to take a rest in the conditions to which I was ordinarily accustomed. In this sphere there was no gravity, which I had come to miss, no top and no bottom; here you needed no soft couches, feather beds, pillows or beds, nor did you need hangers or shelves. Instead, there were simple contraptions to fix things in their places. These were thin threads with hooks that held the objects where they were supposed to be and prevented them from slipping about in disorder; the pots with plants stood at the windows and sunlight gave them life, making them tirelessly bear fruit which very well replaced the most nutritious substances existing on the Earth.

Should gravity make its appearance, all this would break loose and tumble together into a single disorderly heap. The comfortable atmosphere of the environment devoid of gravity is unsuitable for the Earth which has its own style of comfort.

And so, this blissful abode was transformed in advance: top and bottom were defined, a flat floor was laid on the

bottom, furniture, including beds, were placed on the floor, a pendulum clock was hung on the wall, and pitchers of water and jars of oil, and various other terrestrial paraphernalia and articles were put on the tables. . . . But how did your natives manage to produce gravity? the reader will ask.

Very simply and absolute gratis!

They chained the sphere adapted to gravity to a fairly considerable mass which, however, only slightly exceeded the mass of the sphere itself, and they made the whole system rotate about its centre of gravity (in mechanics it is called the "free centre"; its position coincides with that of the centre of gravity). To prevent the system from interfering with the motion of the rings, motion of several metres was also imparted to its centre, this motion being enough for the system to rise over the ring and float independently as a satellite of the planet.

With a speed of 50 m/sec and a chain 500 m long the sphere developed from the centrifugal force a gravity equal to that existing on the Earth.

Suddenly I felt I was in my old surroundings, but I had grown unaccustomed to it and it stunned and crushed me, fettered me and pinned me down; within a few minutes I was begging my new friends to arrange lighter gravity for me. But before help arrived, I had already recovered and become acclimatised. First I lay down on the bed and alternately raised arms and legs as though testing their weight and, as though doubting that weight was possible. Then I sat up, stood up and walked a bit; I wanted to jump, but found I could not—I lacked the energy; I waited a while and then jumped, but not high. I walked over to the clock and touched the pendulum which began to swing, ticking away the seconds. I poured out some water and drank it. I threw an eraser; it described an arc (parabola) and hit the carpet; I tilted the table and the pencils rolled. I experienced everything I had not experienced for a long time.

When, at my request, my friends who flew after me (outside) halved the speed of the system's rotation reducing it to 25 metres, I felt I was only 50 per cent heavier than on the Moon, because the gravity had become four times as weak.

The pendulum swung at half its previous rate and the water flowed more slowly, but I felt much stronger and jumped almost to the ceiling.

I sat down in an armchair and looked about me. Through one window I saw the black sky with stars that did not twinkle, through others the bright, bluish Sun. It seemed as though the entire heavenly firmament with the stars, Sun, the planetoid and its rings were revolving round with me as the centre, making a complete revolution in 63 seconds. My room seemed to be absolutely still. For me my room became a planet. I sought out the fixed points on the heavenly firmament—the poles, round which it revolved so hurriedly. Of course, the axis of a system can be fixed at will; thus any star and even the Sun can be taken as the polar points; in the latter case the Sun appears to be still, shines into the same windows and casts the same shadows.

With a chain 125 m long (but in order to produce the same gravity) the speed will be only 12.5 m/sec and a complete revolution about the axis will take 32 seconds.

This gravity obtained by rotation is eternal and for its maintenance requires no expenditure of power.

They gave me any gravity I asked for.

When the speed of rotation was accelerated the gravity increased and I increasingly felt the roughness of its paws; it got to the pitch when I lacked the strength to rise from my bed or alternately, to seat down on it, and I crashed down on it instead. But when it reached the stage when I could not raise my arms, I gave the signal for the experiments to be discontinued.

I grew tired of it all, and wanted to be once more in the tender embrace of an environment devoid of gravity.

While the rotation was being slowly stopped, I observed the effect of the gradual diminution of gravity on certain phenomena.

On the table before me was a glass of water with a glass tube in it. I saw water trickling from the wash-stand and drops of water splashing one after another on the floor. The more the gravity weakened the higher the water in the tube rose above the level of the water in the glass; the water in the glass also rose higher and higher round the edges forming a deep hollow; the drops of water falling from the stopped-up wash-stand grew larger and larger: at first becoming as large as peas, then as cherries, then apples. They fell to the floor more and more slowly and hit it more and more gently.

Then the water reached the edge of the glass and began to overflow, the tube filled to the top, and the last enormous drop of water from the wash-stand almost hung in the air. Finally, all the water flowed over the edges of the vessels and scattered in all directions leaving a wet place. The pendulum hung motionless to one side, I rose with my armchair into the air, the bodies ceased to fall, everything began to move about, became agitated.... The illusion of gravity had disappeared....

Gravitation between small bodies is more easily revealed in an environment devoid of gravity. Thus inside a sphere whose mass, according to analytical conclusions, cannot exert any influence on the bodies within it, all these bodies have a tendency of mutual attraction; but the speeds derived therefrom are so negligible that the bodies seem motionless and a considerable time is required to notice that they have moved at all.

Two motionless persons of average size which at a distance of 2 metres develop a mutual attraction of 0.01 mg (the weight of a grain of sand) traverse 18 mm during the first hour, about 54 mm during the second hour, and close to 108 mm during the third hour—a total of 180 mm in 3 hours, each body traversing 90 mm.

It would take more than 5 hours for them to come into direct contact with one another.

They could revolve next to each other (properly speaking, round the middle point of the distance from each other) and make a complete revolution in 44 hours at a speed of 1 mm in 26 seconds.

Clearly too much patience is required to observe so inert a phenomenon and, besides, it is very difficult to make bodies motionless; you constantly give them imperceptible jerks and impart enough motion to them to drive them into different corners and, relatively speaking, pretty fast at that.

Lead spheres, weighing 1 kg each, at a distance of 2 decimetres revolve a little faster, i.e., making a complete revolution in 12 hours.

If solid lead spheres with the same distance* between their centres (2 decimetres) are enlarged so that they almost touch, they will make one revolution in 1.8 hours, and this is intolerably slowly.

35. Terrestrial view on an asteroidal ring (continuation). The wisdom and power of my friends were astounding.

On one occasion I said:

"Why don't I ever see our lovely blue sky with the merrily twinkling stars, our mountains and seas? Here, you know, the sky seems black and the stars dead-silver dots."

And seeing how sad I felt, they took the hint and presented to me an absolutely terrestrial view.

Within a few minutes they had carried me off.

At first we flew, then gravity formed and we rolled down a long corridor. Finally, they closed my eyes and when I opened them again, I was sitting on a river bank under a willow tree as though preparing for a swim. I had migrated, heart and soul, to the old world, had an irresistible desire to plunge into the cool watery depths. . . .

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* Incidentally, the time of revolution of contacting spheres does not depend on their size and the distance from their centres.

In the distance were hills enveloped in a blue mist, close by were corn fields, the ears of grain swaying in the breeze, several groves of trees and poor Russian villages. The sky was blue and clear.

"Watch us making big waves on the river," they said.

And they gave orders for the force of gravity to be reduced. The more it weakened the larger grew the waves, and the larger they became the more slowly they rolled. I felt the effect on myself of the lessened gravity because the ground on which I sat became, as it were, softer. I saw the waves rise like mountains, ready to sweep over me.

"On oceans we could make waves several hundred metres high, provided there were sufficient water," they observed.

There was no question of swimming in such a river; but they moderated the agitation of the waves by increasing the gravity to its lunar magnitude (one-sixth of terrestrial gravity). I plunged into the water, and how easy it was to swim! It took little effort to keep on the surface, but to leave yourself to the mercy of fate could probably mean drowning. When I had dressed again and was seated in a boat, rowing, I found that the harder I rowed and the weaker gravity became, the more did the boat rise out of the water. It reached a point where it barely touched the water and was moving very fast. This happened when gravity was reduced 30-fold.

36. A trip round the Sun. Inhabitants without planets. All of us, who live on planets, travel round the Sun. The planet itself is the safe carriage and the tireless horses. It is the same even with you people who live on the Earth. But how would you like to take a trip alone or in the company of good friends without a planet?!

You have seen asteroidal inhabitants freely soaring over their planet and they can even move very far away from it; you have also seen that a cannon-ball on a planet some 500 kilometres in diameter recedes from it forever or, after

making one revolution round the Sun, overtakes it from behind.

Here the point is that the speed you imparted to the cannon-ball is gradually taken away from it by the gravitation of the planet, and the cannon-ball retains only the speed it shared with the planet before, i.e., a speed high enough to prevent it from falling on the Sun but not enough to make it move away from the planet forever. In a word, the course of the thrown body coincides approximately with the orbit of the planet itself.

But, since the body moves almost at the same speed as the latter or slightly faster, they may not catch up with one another for hundreds or even thousands of years.

On all asteroids the inhabitants have special mechanisms which conveniently impart the requisite speeds to themselves and their accessories. Do you remember their multi-tiered trains for communication with the ring? They have something similar to enable them to move completely away from the planet. Incidentally, on the small asteroids, 5 kilometres and less in diameter, a good jump suffices <...> to attain the requisite speed. Vast numbers of the inhabitants of such planets travel round the Sun, forming a series of settlements in space which form a precious necklace adorning the luminary. These are the inhabitants without planets.

On the large asteroids the matter is more complicated.

The last train, or the final, highest platform of the arrangements described earlier, loses gravity, but its speed suffices only for that and is not enough for complete recession from the planet. If a new platform moving in the same direction but faster were placed on this last platform, it would rise and fly away or would break up into links and fly away just the same, although it would not leave the planet altogether.

What can be done?

Rails, with their free ends pointing downwards, are fastened to the platform, and on these rails, already beneath them roll the wheels of the next higher platform; the plat-

form is supported by the platform below and could not be carried away by centrifugal force, if this underlying platform is not able to fly away. Hence it is evident that all the platforms—to the last one on the ground—should be similarly coupled with one another.

Thus, these devices, built separately, are exactly the same as the ones described, but since the speeds of half the higher platforms develop a force greater than the gravity of the planet, and consequently the higher platforms are able to fly off or drag the lower platforms behind them, they are all firmly coupled together.

A planet of the same density as the Earth (as we usually assume), with a diameter of 56 kilometres should impart to the uppermost platform a speed of 50 m/sec, and a planet with a diameter of 560 kilometres—500 m/sec.

In passing from the lower trains to the middle one, gravity gradually diminishes and then altogether disappears in the last train; ascending higher, the relative gravity is again manifested, but changes to the opposite direction and, increasing, becomes equal in the last train to the gravity of the planet.

In the upper trains man is standing upside down in relation to the planet. It is enough, so to speak, to fall off the last train, to fly off the planet entirely and become a satellite of the Sun.

Imagine that the gravity of the Earth has changed its direction, and the Earth, instead of attracting, repels you skywards (into the blue abyss), so that you can barely held on sitting up in a tree, upside down, clinging to whatever comes to hand.

You have the same experience in the uppermost train [of the asteroid]; the centrifugal force presses you against the ceiling of the carriage and if you get out of the window you will fall into the sky.

In relation to the train, this will be a perfectly real fall (at least during the first minutes)—you will be falling like a stone with increasing speed.

The only good thing here is that the gravity pressing you to the ceiling is very weak and even on an asteroid 560 kilometres in diameter it is 22.5 times as weak as it is on the Earth, so that you can easily avoid falling, if your left hand holds on to a ledge on the roof. This effort is equivalent to about 3 terrestrial kilograms, assuming your terrestrial weight to be 64 kilograms.

From the middle train you can fly wherever you please and become either a satellite of the planet or part of its ring; from the lower trains you drop onto the planet; from the upper ones you fly away higher, the closer the particular train is to the uppermost train from which you fly off into space and become either an independent asteroid or part of the solar "necklace".

The many-tiered circular trains of the planet, moving along a meridian and at the same time rotating very slowly with it are thus able to throw off bodies in all directions and, within a certain limit, at any speed desired.

37. How are things managed in a weightless environment? I have already given the reader an idea of the laws of motion in an environment devoid of gravity or in one with a seeming absence of gravity. I shall describe the simplest devices the natives use for all practical purposes.

Here is an apparatus to prevent (to some extent) the vibration or rotation of dwellings and the like; it is fairly stable, not rotatory, despite the forces which can rotate it.

The apparatus consists of a sort of room with two extremely rapidly revolving wheels on two adjacent walls; the massive wheels do not press on bearings and therefore revolve freely, without friction; but when attempts are made to turn the apparatus, to send it in the opposite direction, the wheel axles begin to press on the bearings because of the pressure encountered and give rise to friction according to the speed of the discs, the friction being overcome by weak solar motors. In such a room I was able to move about, turn from side to side and perform all the usual movements, and yet the room did not begin to rotate no-

ticeably, as in the case of an ordinary room without rotating disks.

They make each of the latter in pairs, i.e., it consists of two parallel wheels revolved by motors in opposite directions; they are paired in order to be able to brake or accelerate them (for greater stability), without disturbing the immobility of the chamber.

To this the natives add an apparatus which enables them to set the room in position quite arbitrarily prior to imparting stability to it. It also consists of a pair of mutually-perpendicular, but simple (not paired), motionless wheels. When these wheels are revolved, the chamber also revolves; when they stop the chamber also stops. At first one axle with its wheel is revolved arbitrarily as gently as possible until the other assumes the desired direction. At this point the first wheel is stopped and the other set in motion so that the axle of the first is given the desired direction. Thus the chamber is set up as required—with the axles directed at the stars desired—and then stability is imparted to it. The axles of the wheels usually coincide with the imaginary "free" axes of the chamber. Now I must also describe how translational motion is imparted to it.

For this purpose the chamber has something like a long cannon which shoots cannon-balls. To impart a definite forward motion to the chamber, it is set up so that the cannon points in the direction opposite to the desired path. The cannon is then fired (or the cannon-ball is moved by solar motors) and the chamber flies in the desired direction at a speed of several dozen metres a second, according to the mass and speed of the cannon-ball. By firing another cannon-ball in the same direction we get (approximately) the same speed and fly twice as fast. This is how the desired speed is obtained. The motion can be stopped or retarded by firing cannon-balls in opposite direction. By firing cannon-balls in different directions, we can turn corners and move along broken lines; by ejecting a continuous stream of liquid or small bodies we get curvilinear motion of the kind

required. To keep these cannon-balls from causing damage when meeting bodies during flight, they are made soft and loose in texture, even though they are massive.

For short-distance travels the natives use a long chain with a mass at the end; the mass is released without much force; the chain unwinds and is paid out together with the mass as far as desired. At the same time the chamber moves away in the opposite direction. With a large repulsed mass and a long chain the motion can be pretty considerable. For example, when the thrown mass equals that of the chamber with its contents and the chain is 2 kilometres long, the missile travels one kilometre from its place in any direction. The chain can be made much longer because it does not snap due to gravity, nor does it bend or stretch where gravity is absent. The impact of the cannon-ball can be as gentle as you like, and the longer the chain, the more harmless it is.

Yet the natives rarely travel or live singly; usually a native when he wants to travel employs as a support the mass of others. By pushing off consecutively from very many of his fellow creatures a native does not perceptibly alter their motion yet at the same time acquires the necessary speed and direction.

Of some interest are the joint evolutions of the inhabitants [of an asteroid]. For example, several of them, moving in conformity, take the form of various motionless figures: circles, triangles, etc., the location of the centre of gravity of their total mass remaining constant. Sometimes they arrange themselves in two circular concentric chains. One of the chains, by pushing off from the other, imparts to itself and the other chain motion in opposite directions, thus forming two sets of a round dance perpetually circling alongside each other. Now if the members of one of the sets make a closer ring, their velocity—both angular and absolute—will increase until finally they will lack the power to draw closer, owing to the developed centrifugal force. For example, a tenfold reduction of the diameter of

the ring will increase the angular velocity 100-fold, the absolute velocity 10-fold, and the centrifugal force 1,000-fold. Such a centrifugal force scatters their uncoupled members radially against their will.

Sometimes two of these beings agree to push off from each other as hard as possible by means of some special device. As a result one of them acquires greater speed and describes an ellipse, instead of a circle, round the Sun moving away from the luminary; the other loses part of his inherent natural speed and, describing an ellipse, approaches the Sun. If pairs, rather than individuals, have pushed off from each other, then one of the pairs, for example, that which has approached the Sun can still break apart, one member of the pair coming still closer to the Sun and the other member receding from it. These evolutions are infinitely variable.

The inhabitants of very small asteroids (for example, 1,000 metres in diameter and even smaller) transformed their planet into a guided missile, imparted to it the rotation they wanted and thus changed their diurnal period at will; they also imparted more or less translational speed to their planet which sometimes receded from the Sun in a spiral and sometimes approached it. They drove the planet as we drive horses. When they drew closer to the Sun their year grew shorter, as they receded from the Sun it grew longer. In the latter case the Sun gave them less heat, and their summer turned to winter. On the other hand, as they came closer to the Sun their cold weather was replaced by heat. They changed the axis of rotation of their planet, each time forming a new polar star and equatorial constellations; thus they governed the seasons of the year.

They changed the position of the axis on the planet itself without changing its position in relation to the stars. They changed the plane of their trajectory around the Sun, the trajectory itself, moving in the direction they required. They were in a position to recede from the Sun forever or

be hurled into its fiery abyss serving as an addition drop in the source of solar radiation.

It stands to reason that in all such changes in motion and position, the planet inevitably loses part of its mass, and the more of these changes it undergoes the more of its mass it loses; as for the work these changes require, the planet gets this from the Sun.

One small asteroid was broken up into a circle by its inhabitants so that there was nothing left of the planet and its low gravity decreased another100-fold. The inhabitants were directly interested in transforming their planet into a disk which would receive a relatively tremendous amount of sunlight to give the inhabitants life and power.

This ring, or disk as it dispersed in space, formed a "necklace", a chain of settlements without a foundation, revolving round the Sun like the rim of a wheel revolves round its bush.

A great many asteroids—even large ones—were transformed into such collars or "necklaces". In the Solar System they stretch like thin threads around the luminary. They are invisible to man because, even if they are one kilometre wide, their length of several million or, perhaps, several thousand million kilometres makes them look much finer than a cobweb, scarcely perceptible to the eye, even when viewed through the most powerful telescopes. These threads partly regulate their motion by parting and altering their speed when there is a danger of falling or running into some intolerable minor planet flying too close.

There are no "necklaces" near the large planets. [The large] planets are fatal to them.

38. [redacted]. Let us see how the natives travel from one asteroid to another.

Here is a series of imaginary asteroids, each 6 kilometres, let us say, in diameter.*

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* About the size of Agatha.

Assume that they perform strictly circular revolutions round the Sun in one plane and at about a distance at least twice that between the Earth and the Sun.

Calculations show that the asteroids about 6,000 kilometres apart (even less, 3,000 kilometres sufficing if there are not many asteroids) do not greatly influence each other and cannot under any circumstances collide, especially if, in addition, the planes of their orbits do not align.

Each planet moves at a speed 23 cm greater than the next one immediately following at the closest distance of 6,000 kilometres. It is clear from this that the translational speeds of the asteroids are almost equal and if they do not merge into one (planet) it is only because of their weak attraction (1/2,250th of the terrestrial attraction) which is made much weaker still by the relatively enormous distances between them; moving in one direction they travel for long distances side by side and in sight of each other.

Consequently, one planet will surpass the next by a whole circle, i.e., will meet it again only in 31,000 years. In 100 years one planet outstrips the other by only 1° (1/360 of its circumference).

Clearly, flying from one asteroid to another is not in the least difficult or dangerous. By properly imparting to ourselves on the requisite circuit train, the appropriate speed, say, about 10 m/sec (32 km/hr) we can reach the nearest planet in 10 days. The difference in the speeds is slight, and the impact, if the simple precautions are taken, is negligible. In the event of an error in direction, this can easily be rectified by means of the devices already described (Essay 37).

We know about 350 asteroids between Mars and Jupiter along a length of 46,000 terrestrial radii, each asteroid occupying an average distance of 131 terrestrial radii; but then the asteroids, on the average, also have a much greater mass and, consequently, mutual attraction than do our imaginary minor planets with a diameter of 6 kilometres. The mean difference in their speeds will be about 60 m/sec.

This speed is not so great as to prevent the inhabitants from communicating with each other. It will be remembered that, on the average, one asteroid outstrips another by a whole circle and they meet again in 200 years. Incidentally, the asteroids are actually very eccentric; they by no means revolve in one plane and differ in their masses.

But can we possibly know all of them, if dozens of new ones are discovered every year?*

The inhabitants of the "necklaces" are free and happy beings—they are not slaves to gravity, they can travel wherever they please; a trip from one "necklace" to another, covering many thousands of kilometres, presents no difficulties at all. Such trips are a common occurrence; some travel away from the Sun, others travel towards it. In general, the motion of the "necklaces" barely changes despite the constant role of the support. Such trips are particularly easy between Mars and Jupiter because the asteroids scarcely interfere with them, especially, if the trips cover the space between the part of the "necklaces" farther away from the asteroids. This is even more so, since these parts will catch up with the asteroid only after the elapse of scores or even hundreds of years. It follows that the time available for the trip is very considerable.

Movement in the other intervals between the neighbouring orbits of other large planets is just as free.

It is only somewhat more difficult to travel from one inter-orbital space between two large neighbouring planets into the other.

Let us take, for example, a flight from a zone of asteroids into the zone between the orbits of Mars and the Earth. At a distance of 200 terrestrial radii from Mars, closer to

*The number of all the known asteroids is about 350. Of these 220 are less than 50 kilometres in diameter, 100 planetoids are 50-90 kilometres, and 30 are 90-180 kilometres in diameter; lastly, Vesta, Ceres and Pallas have much greater diameters, the largest of them —Vesta—being 406 kilometres in diameter.

or farther from the Sun, i.e., at a distance of 1,250,000 kilometres, bodies running past Mars along circular orbits like planets do, are in danger of being attracted by it.

Thus, between two "necklaces" insured against attraction by the planet there remains a space of 2,500,000 kilometres. While Mars is on the side opposite to the inhabitants of the "necklaces", they can pass swiftly over this distance in one year, moving at a speed of only 75 m/sec or 270 km/hr (composite speed in the direction of the Sun and not absolute); for outer spaces this speed may appear negligible to us, if we recall that even the multi-tiered trains on the asteroids easily developed speeds 5-6 times as great (500 m/sec); on the "necklaces", where there is no gravity, such speeds are much more conveniently attained.

It should be noted that much more time than one year is available to make a safe flight across the orbit of a large planet, since, for example, Mars catches up with the outer "necklace" on a semi-circumference in only 60 years.

During this time, and even longer, the orbit of the planet can be freely traversed.

Crossing the orbit of the Earth, which has a mass about 10 times as great as that of Mars, is somewhat more difficult but, as calculations show, is also perfectly possible and requires a speed of less than 500 m/sec to be completed in six months. The orbits of other planets, closer to the Sun, can be traversed still more easily, because of the smaller mass of these planets.<...>

38_{1}. Across a planet in forty minutes. On one occasion, I happened to be on a spherical, nonrotating planet which has a tunnel running diametrically through the whole planet. For small planets, not exceeding 400 kilometres in diameter, such tunnels are quite possible; in general, every kind of deviation from the spherical form is possible.

If you jump into this tunnel, you reach the opposite end in about 40 minutes; near the exit you slow down somewhat, grasp the edges and climb out to the antipodes. If

you do not desire to do so, you will [swing] eternally back and forth, like a pendulum. During all this time you feel no gravity in relation to the things you have with you; but do not grasp the walls of the tunnel or friction will soon bring you to a halt. With low gravity it is easy to come to a halt by this method at any distance from the centre of the planet; then we would see that there is no gravity in the middle of the tunnel and that it increases in proportion to the distance from it, right up to the exit.

It is interesting that from whatever point in the tunnel you begin to fall, the return to the former place is completed in one and the same period of time (for a planet of the density of the Earth it is 1 hr 20 min) so that it takes the same time to travel small distances of a few millimetres and long distances of several hundred kilometres. It is like a pendulum: whether the amplitude is considerable or small, it requires roughly about the same time for each swing (the isochronism of swinging).

It is also interesting that in other planets—much larger and much smaller—we also made this diametrical trip in about the same space of time.

Theoretically, if all the planets were of the same form and density, it would always take the same period of time to travel from one of their edges to another. Even if the Earth had a through tunnel, we would dive through it to the antipodes in 40 minutes. Through the Sun we would cover this journey in 1 hr 20 min (because its density is only one-fourth that of the Earth) and through the Moon—in 53 minutes.

It transpires that it takes the same period of time for the enormous diameter of the Sun (more than 1 million kilometres) to be pierced by the force of gravity, as it does for a tiny clay sphere.

38_2. *On three primordial asteroids.* I also once sojourned on a primordial planet left untouched by the inhabitants of the asteroid belt, in commemoration of the past, just as we preserve localities of definite geological interest. Good

God! What an irregular mass it was! From afar, and close up, it looks like a rough fragment, nothing like our comparatively polished Earth. Gravity being very low on it because of its small size is infinitely varied in direction and intensity.

On another occasion I visited a primordial rotating planet of almost spherical form. Owing to the rotation, the relative gravity at the surface of the planet also greatly varied: at the poles of rotation the magnitude was at its greatest and the direction normal, towards the centre, but the farther away from the poles the weaker the gravity became and the more its direction deviated towards the equator, so that a person coming from the poles, as it were, descended an increasingly steep hill, although it was not difficult to keep one's feet on the increasing slope since gravity grew weaker; at some distance between the poles and the equator the direction of gravity coincided with the horizon, i.e., it was parallel to the surface of the planet, and you seemed to be descending a sheer wall. Further on, the ground presented itself as an inclined ceiling which at the equator became an ordinary horizontal terrestrial ceiling, and you had to grasp at whatever came to hand in order not to fall off the planet. Here you had to stand on your head in the manner of boys and acrobats the only difference being, however, that the blood did not rush to your head, your face did not redden, and the terrible terrestrial gravity did not press you to the ground, on the contrary, it tended to pull you lightly away from the ledges to which you were clinging. Here there were no stones; they had all flown off the planet due to centrifugal force, but as they circled round the planet they approached it from time to time.

Once, the ledge I was clinging to broke away, and I began moving away with it from the planet; I pushed off from the fragment as hard as I could causing the fragment to move rapidly away from me and the planet, whereas I approached the planet; but as this time I fell on to

a smooth part of the planet and there was absolutely nothing at all I could cling to, I had to move away from the planet again. At first I moved normally in relation to its surface and with increasing speed; then I noticed I was no longer receding from it, but even beginning to approach it once more. I did not hit it but merely brushed against it, although at an entirely different spot, then began to move away normally from it again. My impression was that the sky repelled me with invisible hands and put me on the planet, but the planet also refused to receive me and similarly repelled me without a blow, mysteriously. Thus I kept rising and falling and always at different spots on the planet. It was a rare occurrence to fall twice on the same spot.

The faster the rotation of the planet, the farther do the bodies that have fallen off the equator recede. But for a complete removal from the planet quite a low speed of rotation is required for small asteroids. At that speed things are thrown off once and for all by centrifugal force, and become satellites of the Sun.

There was one other almost spherical and rotating planet, but with a relatively enormous mountain on its equator. Everywhere on this planet gravity had the upper hand, except for the mountain, the upper part of which moved more rapidly and so developed a centrifugal force that exceeded the planet's attraction. As we ascended from the foot-hill of the mountain, we observed that the gravity grew weaker and weaker and at some point disappeared altogether. Above this critical point it reappeared, but in the opposite direction, tending to throw everything off the ground, and you had to walk on your head—on your hands, to be exact—grasping at whatever came to hand in order not to fall off the planet.

On another similar planet there stood a terribly tall tower, thin at the top and bottom, like a spindle, and without any support, i.e., it did not touch the planet. We walked under this air castle and wondered why it did not drop

on our heads. The point is that, owing to the centrifugal force, the upper part of the tower tended to fly away, while the lower part pulled it in the opposite direction. Its form and position were such that it was invariably in a state of equilibrium.

38_3. *An asteroid with a moon.* I shall tell you briefly about another planet 56 kilometres in diameter, which was situated between the orbits of Mars and Jupiter. It had a satellite, 6 kilometres in diameter. The satellite moved at a distance of 60 radii of the planet (1,680 kilometres), at the rate of 4.5 metres a second (about 14 km/hr), making a complete revolution in 28 days, like our Moon.

From the planet it was, of course, not difficult at all for the natives to reach the satellite (Essay 38); it took them roughly a day. They had long since grown tired of this satellite because with the power of its attraction it caused perturbations and disorder in their rings as they revolved round the planet.

So they decided to do away with it as a satellite and transform it, right to the centre, first into a thin disk and then the disk into a planetary ring.

Owing to its symmetrical position and continuous action such a ring no longer produced perturbations in the planet's own rings and did not hinder them from expanding to the very satellite that had been transformed into a ring.

Thus, the planet with the satellite formed a system like that of Saturn with its rings.

The satellite was transformed into a ring with the aid of solar motors in the course of 10 years. But it later took 1,000 years completely to change the planet into a disk. After that the disk easily changed into a solar necklace (Essay 37).

39. *Temperature at different distances from the Sun.* The power of the Sun's rays increases as their distance from the Sun decreases in absolutely the same manner as the force of the Sun's attraction. It follows that in the solar

system space the temperature varies endlessly. In a way it is true, but artificially the temperature may differ very much in one place and, on the other hand, may be the same at different distances from the Sun. By very simple methods the natives make it as cold as they like where in ordinary conditions they should disintegrate from the heat.

Even at the distance of the Earth and in its atmosphere a black surface, in certain circumstances, becomes heated to 100°C. What is it like, then, in a vacuum under the continuous action of the Sun's rays and at a distance, for example, 10 times nearer, at which the Sun appears to have a diameter 10 times as large and to be 100 times as vast, bright and warm?!

Imagine that in so hot a spot the inhabitants [of an asteroid] are under the shade of a shiny metal sheet which does not lose its reflective capacity, despite the rise in temperature. The screen repels the greater part of the Sun's rays, although it heats to 300-400°C.

It disperses this heat in space in every direction, and the natives in the shade some distance from it receive a relatively small amount of heat.

By using another screen behind the first, and standing in the shade cast by the first, and heated by it alone, we can get a temperature that at least can be borne by living beings.

Using several screens, placed one behind the other, it is possible to reduce the temperature of, so to speak, the very nose of the Sun, to the point where water and alcohol freeze.

Now you believe that my distinguished friends were not afraid of flying close to the Sun, although their permanent residence was not very near it.

On the other hand, those who receded from the Sun raised the temperature artificially; they had numerous methods of doing this. Picture to yourselves, for example, a reflector or a concave mirror and a living creature in the cone of the rays reflected by it. It stands to reason that

as the creature approaches the apex of the cone it raises its temperature as required.

Even when these mirrors are of an enormous size they may be thin and fragile as you like; owing to the absence of gravity there is no need to fear that they will break; nor is there any danger of their losing their lustre, since there is no atmosphere.

The colour of the natives and their clothing also enormously affect the amount of heat they assimilate. An object with its black half facing the Sun and the white, shiny half in shadow is in the best possible conditions as regards the degree to which it is heated by the Sun.

By this simple method, the natives obtain the temperature of the human body even in the asteroidal zone. If you are hot in this position, turn at a small angle and the temperature will drop.

Because of its constancy, this outer-space temperature is extremely healthful; no day or night, no wind, damp nor rain—nothing disturbs its perfection and complete dependence on rational beings.

Constant and exactly how you like it! Is it not truly wonderful!? Simple screens either lower or raise the temperature depending on whether they are protecting the object from loss of its own radiation or from the radiation of the Sun. While protecting a body from loss of its own heat and at the same time reflecting the Sun's rays on to the object itself, the screen still further helps to raise its temperature.

The side screens along which the Sun's rays only slide are also effective; they retard the radiation from the body. Poor heat conductors, i.e., the clothing, also exert some influence.

Using a variety of devices, the natives came so close to the Sun that its rays melted glass, and it oozed like water, while chemical compounds broke up into their components with amazing rapidity.

They also moved so far away from the Sun that in the shade, under the protection of a consecutive series of screens, they produced such low temperatures that gases were converted into liquids and, on freezing, became as hard as steel. Hydrogen was well preserved in a shiny metallic form (like blue steel).

It is of an enormous convenience to be able to produce tremendous temperature contrasts, wherever needed. The natives made use of these contrasts for transforming the energy of the Sun's rays into mechanical work by the simplest and most advantageous methods. We have already described one type of their solar motors.

40. From star to star or from sun to sun. Once I asked my friends:

"Well, then, you live by the Sun and need no nourishment but light. But what will happen when this light vanishes? For the Sun will not shine forever! Our terrestrial mathematicians find that it will shine for another dozen million years, after which it will be covered with a dark crust or heavy clouds and will be like Jupiter, which is of no use to us at all. Must you perish then?"

"To begin with, your mathematicians also know that universal gravitation is an inexhaustible source of energy; their assumption that the Sun will cease shining is based on the idea that the Sun cannot become denser than the Earth, or something of the kind. This assumption is wrong. Secondly, even if the Sun stops shining for a time, and we shall know about it many thousands of years ahead, there is nothing to stop us flying to another Sun and living there until it becomes exhausted. There are stars with diameters 10 times* that of the Sun, and according to your own theory these stars should shine at least 1,000 times as long as the Sun.

"We shall wander from star to star, as they become

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* The diameter of Sirius is 14 times that of the Sun.

extinguished, until the same stars begin shining with a new, more abundant, more resplendent light.*

"But how is this so," I objected, "the interstellar distances are so frightful.... When will you reach another home, another source of life, if it takes light months and even years to traverse these distances?"

"It does take light years, and we cannot move with the speed of light," they answered. "On our 'necklaces' we develop speeds that equal those of the planets, i.e., up to 100 km/sec and more. Thus, if light requires years to traverse a certain distance, we shall travel for thousands of years covering the same distance; if light requires months, we need hundreds of years."

"But what do you subsist on during these thousands of years? The weak stellar light, perhaps, that accompanies you on your cheerless voyage?"

"No, we live on the reserves of solar energy, as you always do."

"You mean you will become transformed and take nourishment like we, human beings, do?"

"Not at all. We only convert the reserves of energy into light which, like the Sun, keeps us alive. It is the same as when you convert the energy of the Sun, contained in coal, into mechanical work and the latter into electric light."

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* According to the Boscovich hypothesis, accepted with minor corrections by the great Faraday, matter consists of centres of forces, of mathematical points interconnected by attraction or repulsion, whose law for molecular distances is unknown. If this is so, there is nothing to prevent matter from infinitely becoming condensed. This condensation can serve as an inexhaustible source of energy liberated by suns in the form of heat and light. For example, water was long considered to be incompressible. But what are the facts today? According to Cailletet, water contracts in proportion to pressure, like gas, only 20-30 times as weakly as air contracted to the density of water. Experiments were performed up to 705 atmospheres. There are no reasons to regard contraction of bodies as *limited*. Solids contract similarly (Buchanan). Thus the pressure in the centre of the Sun should condense steel 600-fold.

"But how much energy, what reserves of it, do you need for thousands of years and for millions of creatures?"

"The reserves are carried without any effort in infinite quantities and endlessly according to the well-known laws of inertia. Each of you requires but a small reserve for 1,000 years of subsistence, whereas we need very little indeed. One cubic kilometre of grain contains 1,000 years of nourishment for 3 million people; ten cubic kilometres of it contain enough to feed 3,000 million people. On our rings and necklaces the Sun prepares such a reserve in just a few seconds. Finally, we can exist in a state of blissful lethargy, and in this semicoma a thousand years passes like a minute, like your pleasant deep slumber.

"This state requires nothing but a definite temperature and an extremely small amount of light."

41. Return to the Earth. How many years had passed I do not know. The time came for me to leave my good genii.

With my human, sinful heart I had grown very much attached to them, to their life, to their environment and kindly solicitude that surrounded me.

I found them as beautiful as precious ancient vases and admired them as the finest productions of the human mind and heart... <...>

Yes, my friends, I have told you many wonderful things, but not even a millionth of what actually existed there.

And yet, where had I been and what had I seen?! Only the solar system. But how many are there of these systems? Billions in our Milky Way alone. How many galaxies are there? Who can tell? The world is infinite.

Chapter 8

THE ENERGY OF SUNLIGHT

42. The total energy of the Sun. We said (Essays 3 and 4) that, if we imagined the Earth as a small pea, the Sun would be a large water-melon 180 steps away from it. This

shows the relatively insignificant amount of solar energy representing the Earth's share.

But the energy of all the rays emitted by the Sun is so enormous that, if it were fully converted into mechanical work, it would overcome the mighty attraction of the parts of our planet, would mechanically disintegrate them into mist in a very short period of time, and would change their shapes the more easily by turning them into cubes, buns, rings, etc.

Here we should note two things: firstly, no physical energy is fully, without a trace, converted into mechanical energy, but engines can be designed which in a vacuum can convert one-fifth (approximately) of the solar energy into mechanical work; secondly, I am not here dealing with the methods used for separating the parts of the planet or changing its shape, I am only assuming that there are such methods and that they are so perfect that in this process the work of the rays is fully utilised.

The whole outline which now follows will take into account similar conditions which are, in practice, impossible.

Jupiter, our largest planet, disintegrates mechanically into an infinitely rarefied mist* in the course of 115 years; the Earth is disintegrated by the total solar energy in 4 days, the Moon in 3 minutes; a planet or a satellite half the diameter are disintegrated in less than one second.

This energy is enough to heat the cold (by supposition) Earth to 3000°C in 24 hours. It can heat a mass of icy water equal in volume to the Earth to 100°C and then convert it to steam in 4 hours.

The solar energy liberated in 3 days corresponds to the energy of a quantity of coal, equal in volume to the Earth (assuming the density of coal as unit), when burned in oxygen.

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* Here the relatively insignificant force of cohesion of matter (adhesion, etc.) is ignored.

In one second it produces more power than that from food prepared to feed 2,000 million people (more than the population of the Earth) for 25 million years.

Here you involuntarily exclaim: what enormous wealth our luminary sends out every second, yet we cannot take advantage of it, and it slips through our fingers!

In less than one day a volume of water equal to the volume of our Earth is chemically decomposed by the Sun's energy into its constituents (hydrogen and oxygen).

The total energy of the Sun fully converted into mechanical work, can impart to the Earth its diurnal rotation about its axis in 11 hours and to an asteroid, one-tenth its diameter, a similar diurnal rotation (a complete diurnal turn about its axis) in 0.5 sec.

The translational speed of the Earth along its orbit is acquired in almost a month; the motion of the Moon round the Earth in 3 seconds.

It is this energy in particular that is extremely great in relation to the transformation of the small asteroidal planets which it rubs, crumples, changes to any shape, breaks up into mist, disintegrates chemically and physically, imparts rotation and translational motion, removes from the Sun or brings closer to it, drives onto the Sun or throws away into void <...> in the course of a few seconds or even fractions of a second. Compared with this force the Earth itself is nothing: condensation of its atmosphere into liquid, every kind of disintegration—chemical, mechanical and physical—of the substance of the planet and the imparting to it of any shape or motion, are a matter of a few days, at most a few months.

43. Part of the energy received by the planets. But the planets make use of only a small part of the solar energy. For example, the Earth receives from the Sun only a 2,500-millionth part of the energy that the latter dissipates in space. All the planets together receive extremely little energy from the Sun. Saturn, for example, not counting its rings, receives about as much as the Earth, Jupiter

about 4 times as much, Mars about 8-9 times less, and Venus about twice as much, so that hundreds of millions of times as much energy is dissipated as is utilised. Ah! and how is it utilised?*

Let us assume that the energy of the Sun's rays falling on the Earth is distributed equally over its surface and is completely converted into mechanical work; then, each square metre will receive 0.5 hp working incessantly day and night, while 5 square sazhens will receive 75 hp. The work of such imaginary machines would lift a layer of water 1 metre thick and uniformly covering the entire Earth at the rate of 5 cm/sec; in 24 hours this mass of water will be lifted to a height of 4.32 kilometres, and in 3 months it will reach the extreme limits of the atmosphere (about 300 kilometres).

This work is at least 17 million times greater than that performed by all the people. If five able-bodied workers, capable of working tirelessly, were placed on each square metre of the Earth's surface, their work would equal that performed by the Sun's rays on the Earth. Actually the Sun's rays perform much less mechanical work; it produces the winds and sets the waters in motion; the greater part of it is converted directly into heat which sends out rays into outer space.**

If the gravity were the same on all planets, the mechanical effort of solar power would be the same everywhere, i.e., on each planet a layer of water 1 metre thick would steadily rise at the rate of 5 cm/sec; but on the Moon, for

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* If we assume that each hectare of the Earth's surface yields an average of 2 tons of grain, sugar and other nutrient substances a year, we will find that only 1/5,000th part of the solar energy is being utilised.

** In the course of time all the mechanical and chemical work of the Sun is converted into heat. Only here and there peatbogs and the like, representing the potential energy of the Sun, are accumulated. Formerly these reserves accumulated more intensively, forming heavy seams of coal.

example, the gravity is 6 times less, and the same layer of water would therefore rise for nearly 0.33 m/sec. It follows that on the small planets the relative action of the Sun's rays is much more pronounced.

The entire Earth is mechanically disintegrated by the energy it receives in the course of 26 million years. Have I not astounded you with the power of gravitation? As a matter of fact, for large planets it is very tangible. But let us take the small planets! The Moon, for example, is disintegrated in only 170,000 years, and the asteroid* 6 kilometres in diameter, invented and described by our crank (Essay 31), is disintegrated by the energy of the rays received by the planet in only one week; the next asteroid, 56 kilometres in diameter in 20 years, and the still larger one (560 kilometres in diameter) in 20,000 years.

But we have seen that, being able to form rings round themselves, the small asteroids can make use of incomparably more of the Sun's energy; if we assume that the surface lighted by the normal rays of the Sun is only 100 times greater, then the periods of time given will be considerably reduced. For example, the disintegration of the asteroid 560 kilometres in diameter will take only 200 years.

The periods of time required to alter the planets into all the possible shapes are shorter than those indicated. It also requires less time than indicated for the above figures to alter a planet into a thin rotating disk consisting of rings (like the rings of Saturn) revolving at different speeds and overcoming by their motion the force of attraction of their parts.

Incidentally, it requires only a little less work to transform the whole planet into a very thin and, consequently, weakly rotating disk.

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* Or the minor planet Agatha, assuming that it is spherical and has the same mean density as the Earth (5.5).

Although the existence or, to be exact, the formation of rings, like those of Saturn, around the large planets is inconceivable because of the enormous speeds, which must be imparted to them, to prevent them from falling on the planet (or being destroyed by gravity), and because of the resistance of the planetary atmospheres (whence the process of motion will have to be begun), and presumably for many more reasons, nevertheless, trying to give the reader a clear idea of the relation of the Sun's energy received by the planets to the energy of gravitation, I shall give here the results of calculations of this nature.

A disk 1 cm thick of a density 3 material (almost the density of aluminium) consisting of a series of rings rotating at different speeds and having a diameter 10 times as large as that of the Earth is formed in about 3 years (2.63 years) round our planet by the energy of the rays it receives.

If we take into account the fact that with an increase in the number of rings or in the size of the disk the force forming it also increases, then the time required for its formation will be much less.

A similar disk on the Moon with its diameter of 10 lunar diameters would require 40 days' work.

If we disintegrate (mechanically) the planet to its very centre, i.e., completely, and in doing so use the continuously and rapidly increasing surface of the disk as a [condenser] of solar work, it stands to reason that this disintegration can be accomplished in periods of time which are not at all as dreadful as those we have given. In this case it would not take the Earth 26 million years and the Moon 170,000 years to disintegrate. Theoretically, these periods of time could be reduced a thousand times.

I repeat that all this is impossible in practice and, if at all applicable, only to the small asteroids that are not surrounded by atmospheres and have diameters of only some hundreds of kilometres <...>.

Chapter 9

GRAVITATION AS THE CAUSE OF THE SPEEDS AND RADIATION OF HEAVENLY BODIES

44. Formation of galaxies and their rotation. Formation of suns with planets and their satellites. Their rotation. Under the influence of the condensation of matter by the force of gravity, the primordial nebula divided into innumerable nebulae of the second order. These divided into numerous nebulae of the third order, etc., just as the outer layer of the Earth, contracting from heat and loss of moisture cracks into large and small parts, or as a large mass of water vapours, condensing in the air, forms drops.

We cannot solve the problem as to the order of nebula from which were formed our disk-like Milky Way and similar groups of stars, which from the Earth look like more or less rounded spots of mist because of their remoteness.

For the sake of simplicity we shall consider that the nebula from which the Milky Way and similar groups of stars were formed was one of the first order. Therefore, the Milky Way is a nebula of the second order, and the nebula from which the solar system and the like were formed is a nebula of the third order.

My question is: when the first nebula that did not, we assume, have a common rotation was dividing into parts, was it possible that during its break-up these parts did not get a common, even if extremely weak, rotation?

If two men were to pull each other by the hand, then undoubtedly in addition to translational motion, they would certainly impart to each other rotatory motion as well, which would immediately be destroyed by friction against the ground. Swing a pendulum on a thin thread by hand so that it does not rotate. It is impossible to throw or move anything so accurately that it is not given just the slowest rotation.

Push a stone on smooth, clean ice and you will have one more proof of this. According to the theory of probability, when nebula is broken up, its parts are given reverse rotations.

According to the laws of nature, a rotation of all the parts in one direction (assuming that the first nebula did not rotate) is impossible, but more or less reverse rotations are admissible and necessary.

Thus during the break-up of the principal nebula the nebulae of the second order acquired rotatory motions which, however slow they may have been at the outset, accelerated increasingly as the nebulae condensed. Having a speed of a few metres at the periphery (along the edges) they had increased this speed many hundred thousand times when, owing to condensation, the diameter of the nebulae reached the size of the Milky Way or similar stellar groups. This conclusion is a strictly mathematical one. The work of rotation is acquired, during the condensation of matter, by the potential energy of gravitation, the supply of which is theoretically infinite.

But do the stellar nebulae and the Milky Way really have a common rotation?

Their disk-like shape convinces us that this is so; the motion of the solar system towards the constellation of Hercules, i.e., almost in the plane of the Milky Way also confirms this.

To proceed, assume that the nebula of the second order, say, the Milky Way, for example, condenses in its turn; it breaks up into billions of nebulae of the third order, each of which gives rise to a planetary system with a central luminary—a star or sun.

Of course, here the same thing must happen as did during the break-up of the nebula of the third order; for example, rather weak rotation was imparted to the one that gave rise to our solar system; this rotation was added to the common motion, which although also rotatory, had such a relatively enormous radius of curvature that this

original motion may be considered almost rectilinear. This explains not only the translational motion of the solar system (around some centre, somewhere far distant in the Milky Way) but also the rotation of the Sun and all the planets according to the well-known law (Essay 5).

As the tertiary nebula condenses, its weak rotation intensifies. During this condensation the nebula breaks up, as usual, into parts or rings which as they break up, in their turn, in most cases form spherical masses or give rise to planets with their rings and satellites.

The break-up and acceleration of rotation described above recurs with these, at first spherical, nebular masses of the fourth order and bodies of the fifth order are formed, which give rise to the planetary satellites or rings like those of Saturn.

This theory advanced by Laplace explains excellently the motion and rotation in one direction of the Sun, planets and their satellites.

45. A grand picture of a Universe full of marvellous, living creatures. Without as yet touching upon gravitation as the cause of the radiation of the suns (from afar—the stars) for millions and even billions of years, let us turn to the grand picture that the mind's eye has conjured up.

In the Milky Way alone, telescopes show billions of suns. Yet how many similar galaxies there are, which taken as a whole are a mere grain of sand in the edifice of the Universe!

The innumerable stars, or suns, shining (if we were to approach them) even more brightly than our Sun, are surrounded by still more countless numbers of planets—dark heavenly bodies receiving heat and light from their suns.

Our solar system counts them in hundreds (350); one of them is called the Earth. But who can tell how many of these earths there are in the world, and existing in conditions almost the same as those of our Earth?!

Is it probable for Europe to be inhabited and not the other parts of the world? Can one island have inhabitants

and numerous other islands have none? Is it conceivable for one apple-tree in the infinite orchard of the Universe to bear fruit, while innumerable other trees have nothing but foliage?! Spectral analysis indicates that the substances of the Universe are the same as those of the Earth. Life also extends everywhere throughout the Universe. This life is infinitely varied. If life is varied on the Earth in relatively uniform circumstances how infinitely varied must it be in the Universe, where any conditions are possible?!

All the phases in the development of living beings can be seen on the different planets. What humanity was like several thousand years ago and what it will be like in a few million years—all this according to the theory of probability can be found in the planetary world.

All that which is marvellous, and which we anticipate with such a thrill, already exists but we cannot see it because of the remote distances and the limited power of our telescopes....

ON VESTA

Let us imagine ourselves on Vesta. Although this is not freedom, it is a foretaste of freedom. Vesta is the largest asteroid. It moves round the Sun almost in a circle. If it is spherical, its mean diameter is not more than 400 kilometres. If it has the same density as the Earth, the gravity on it is 30 times as low as on the Earth. If there are liquids and gases there, the liquids should scarcely evaporate and the gases should have an enormous molecular weight (at least 5 times that of oxygen) in order not to be dissipated at such low gravity. All this is possible. Even on the Earth there are liquids which scarcely evaporate. In this case life can be engendered and can exist in these liquids as in our ocean or atmosphere. Only oxygen will be replaced by some heavy gas or non-evaporating liquid. One transparent liquid is also enough, in which case this liquid will be an atmosphere for the living being.

The living beings on Vesta frolic and swim about in their liquid medium like fish; sometimes they leap out of their sea (like flying fish into the air) into the vacuum, or crawl on to heights that are not submerged. But here they begin to gasp and pant and hurriedly plunge back into their medium.

Some of these creatures subsist on plants and the weakest living beings, others are nourished by the Sun alone, like plants, yet others combine the functions of plants

and animals, like our actiniae, and so on; in a word, they contain chlorophyll.

The rays of the Sun penetrate the transparent covering of their bodies and produce chemical phenomena which engender life.

These creatures crawl out of the seas on to the heights in the vacuum where they take delight in the primordial power of the Sun's rays. The process of life continues in these creatures in the vacuum but their bodies lose part of their fluids, although these fluids evaporate very weakly. Within a few hours these creatures have to go back to their sea, like our aquatic animals which sometimes come out of the water.

Some of them have a covering permeable to rays but almost impervious to matter. Such creatures can remain in a vacuum for an extraordinarily long time. They very rarely have to renew the substance lost from their bodies, either from the liquid or from a surrounding mineral mass. After swallowing this mass they tightly close their mouths.

In the beginning these creatures spent part of their lives in oceans and the other part in a vacuum. Later the first period (in liquid) grew increasingly shorter and finally it ended. The creatures were born and lived all their lives on land and in a vacuum. This phenomenon is similar to the adaptation and evolution of the Earth's aquatic animals into land animals.

These creatures become more and more intelligent. By various artificial methods they adapt themselves to life in a vacuum more and more, constantly improving it.

In time their oceans disappeared, and the population in them perished; but the creatures on land survived and prevail.

But how could human beings live here? Let us assume that these creatures are more civilised and wiser than human beings. And this must inevitably occur, if we give them enough time for civilisation; then they will help us

to settle on Vesta. They build spherical or cylindrical chambers from strong net frames with numerous transparent window panes. These chambers contain oxygen (0.1 density of the air), a little carbon dioxide and water vapours. They also have fruit-bearing plants growing in humid soil. They bear the fruit required for our nutrition. The plants produce food and oxygen. On the other hand, our excretions serve as food for them. We breathe, feed and excrete, and so do the plants. An eternal, monotonous exchange, eternal energy and life.

We live in the cylinders as if we were at home. But we can also get out of them into the vacuum, for which purpose we have to wear special clothing. We put on very elastic and very thin clothing which is impervious to matter. Rarefied oxygen continuously circulates between the covering and the skin. Before the mouth, nose and eyes there is a larger space, before the eyes—transparent glass. We breathe in this oxygen and give out carbon dioxide and other gases and vapours. Passing through special appendages of the clothing these are absorbed, while oxygen is continuously liberated from another appendage. One kilogram of oxygen is enough for a whole day of strenuous life. But since a human being gets tired and wants to eat after 5-6 hours, about 200 grams of oxygen in a weak chemical compound and in the liquid state is quite sufficient.

Neither the clothing nor these insignificant appendages can inconvenience or burden the human being. The machine with the pumps, the covering and the substances, which absorb the human excretions and give oxygen, weigh together not more than 3 kilograms, which on Vesta is equivalent to only 100 grams.

On Vesta we make ourselves at home. In the vacuum we do as we please. And when we get tired, hungry and thirsty we enter our transparent cylinders, take off our suits, eat, drink and sleep, i.e., do the same as on the Earth.

We walk freely on the surface of Vesta in our light suits, we breathe freely and look about us.

To begin with, the temperature! The average distance from Vesta to the Sun is 2.36 times as great as from the Earth to the Sun. The temperature of the dark surface of the planet, with which our bodies merge, is about 0°C, according to the table and calculations. This is a very low temperature, especially since it is the maximum; but there is nothing to prevent us raising it by various means.

To keep warm, let us, for the time being, wear warm clothing. It is 30 times as light as clothing on the Earth, and will not hamper us in any way, but will merely keep us warm.

We look about us. The diameter of the Sun appears two to three times as small, yet the Sun shines intolerably. In intensity the light is very like a solar eclipse in a clear sky and at its low phase (1:6). The ground of the planet also shines brightly, making our pupils contract. We see only the largest stars in a black sky.

But if we stand with the back to the Sun and shade our eyes from the light of the ground with the palm of the hand, we shall see a little later, when the pupils have dilated, countless numbers of stars. It is also good to look through a cone blackened on the inside.

The sky looks like a vault as it does from the Earth, only it is not flattened at the top, but is perfectly spherical. It is as black as soot and is studded with the same constellations, without the least change, that are seen from the Earth. But there are many more stars; they do not twinkle and to people with good eyesight they look like points without rays. It is the same at night, only then there seem to be more stars.

Zero temperature on Vesta, or in the vacuum in general, is not at all the same as it is on the Earth, especially in a strong wind. Loss of heat in a vacuum takes place only

by radiation. Thus it is difficult even to imagine how warm it is (in the lightest of clothing) on Vesta at zero temperature and even below. If you place screens, which very well reflect radiant energy, on five sides of you and allow free access to the Sun's rays on the sixth side, the temperature of the body can be raised greatly. But there is no need for it now. On Vesta it is enough to have light, black clothing and the Sun's rays. The rays can cause sunstroke because they are not weakened, not rendered harmless by an atmosphere, but in this case, properly dyed clothing and a transparent plate before the eyes offer good protection.

Let us move about, lift weights, work, talk, etc. Our words are not heard, but if a thread is stretched between the suits of two human beings, they can converse splendidly even over an enormous distance.

On the Earth I can freely carry someone of my own weight. This means that I am actually carrying two people—myself and the other person. On Vesta I can carry with the same ease 30 times as much, i.e., 60 people—59 and myself. This means 4 tons without any strain; or 4 cubic metres or 8 barrels of water.

On the Earth, by crouching down about 50 cm, I can, by straightening up swiftly, jump another 50 cm, i.e., my jump totals 1 metre. On Vesta the same effort results in a jump 30 times as high, i.e., 30 metres. This is the height of a 10-storied house, a very tall pine-tree or a fair-sized hill.

Acceleration on Vesta is 30 cm/sec. This means that when a body falls it drops 15 cm during the first second. In a vertical jump a man acquires in the first moment a speed of about 4.5 metres. It follows that when a man on Vesta jumps he rises for a period of 27 seconds. It takes him as long to descend. This means that the jump will require 54 seconds, i.e., about a minute. Just think what you could do during such a jump!!!

The best long jump should be made at an angle of 45° to the horizon, in which case the vertical rise will be only half as high, i.e., 15 metres, while the horizontal displacement will be 60 metres. This means that on Vesta one can easily jump across ravines and ditches as broad as rivers, and over trees and buildings 15 metres tall. And all these jumps can be made without a preliminary run.*

* Written before 1919.

OUTSIDE THE EARTH

1. THE CASTLE IN THE HIMALAYAS

Hidden somewhere among the loftiest ranges of the Himalayan Mountains there stands a beautiful castle. In it live a Frenchman, an Englishman, a German, an American, an Italian, and a Russian. Disappointment in people and the joys of life drove them to seek refuge in seclusion. They found happiness in science. The meaning of their life lay in imaginative thinking, which drew them together in an anchoretic brotherhood. They were fabulously rich and could freely indulge their scientific whims. Costly experiments and installations continually taxed their purses, but could not deplete them. Their only contacts with the outer world were for the purpose of those installations, the building of which required many people, but as soon as everything was ready they returned to their researches and their seclusion. The only other inhabitants of the castle were the members of the household staff and workers, whose attractive houses nestled in the valley.

2. THE JOY OF DISCOVERY

The top of the castle was occupied by a spacious glazed hall where our anchorets were especially fond of gathering.

In the evening, after sunset, planets and countless stars shone down through the transparent dome. Thoughts

inevitably turned to the sky, and the conversation would drift to the Moon, the planets, and innumerable distant suns.

What dreamers they were! Time and again they would elaborate fantastically bold projects of travel through stellar space, but their own vast knowledge mercilessly shattered their dreams.

One clear summer night three of our friends were engaged in a lively conversation. Suddenly the Russian burst in like a whirlwind and began hugging and pummeling the three men till they pleaded for mercy.

"Would you kindly explain what all this means?" the Frenchman Laplace asked when he had finally extricated himself from the Russian's arms. "And what were you doing all this time in your study? We even feared something had happened to you during your experiments, and we thought of forcing the door."

"I've invented something terrible! No, not terrible, but amazing and wonderful!"

"Well, what is it? Don't act like a madman," said the German Helmholtz, who had suffered most.

The flushed, sweaty face and dishevelled hair of the Russian were signs of an unnatural inspiration, his sparkling eyes expressed bliss and fatigue.

"We reach the Moon in four days. . . . We escape the atmosphere in a few minutes, we reach interplanetary space in a hundred days!" the Russian, whose name was Ivanov, blurted out.

"You're mad," said the Englishman Newton, gazing at him intently.

"Or in too great a hurry, to say the least," Laplace ventured.

"True, gentlemen, I'm carried away with excitement, but please call in the rest of our colleagues and hear what I have to say."

The others soon came and they all gathered about a

large round table, and looked up to the sky from time to time as they waited impatiently for the Russian's announcement.

3. DISCUSSION OF THE PROJECT

"My friends," the Russian began, "my idea is most simple."

"Judging by appearances, we had expected more," remarked the Italian Galileo, who had already been briefly informed of the preceding events.

"You know what is meant by the energy of combustion of different fuels," the Russian went on. "The combustion of a ton of petroleum, for example, develops an amount of work capable of lifting an identical mass to a height of several thousand kilometres from the surface of the Earth. A ton and a half of petroleum is capable of imparting to a mass of one ton a velocity sufficient to leave the Earth forever. . . ."

"In other words," the Italian intervened, "a mass of fuel 50 per cent larger than the mass of a person can impart to him a velocity sufficient to leave the Earth and travel around the Sun. . . ."

"Ivanov has probably invented a giant cannon," Franklin, the American, declared. "But, firstly, this is not new, and secondly, it is totally impracticable."

"We've discussed this at length and long since rejected the idea," Newton added.

"Please let me continue!" The Russian said in a vexed tone. "You're all wrong." The others stopped talking and he continued. "You might call it a cannon, but it's a flying cannon, with thin walls and it shoots gases instead of shells. Have you ever heard of such a cannon?"

"I don't follow you," the Frenchman said.

"But it's so simple, I have in mind a kind of rocket."

"And that's all?" the impetuous Italian asked, disappointed. "A rocket is a mere plaything. You can hardly sur-

prise us with that. You don't mean to say that you want to penetrate into outer space in a big rocket?"

The others smiled, but Newton pondered while the Russian replied.

"Yes, in a rocket, but appropriately designed. It may seem ridiculous and impossible, but strict calculations indicate the contrary."

Newton listened attentively, the others contemplated the starry sky.

When they turned to Ivanov again he went on.

"Irrefutable calculations reveal that the blast of an explosive from a gun barrel of sufficient length can develop a velocity of 6,000 metres per second. If the mass of the gun is equal to the mass of the ejected gases, the former will receive an oppositely directed velocity of 4,000 metres a second. If the mass of the explosive is three times that of the cannon, the latter's velocity will reach 8,000 metres a second. Finally, if the barrel's mass is seven times greater it will attain a per-second velocity of 16,000 metres, which is more than necessary to leave the Earth and travel around the Sun."

"The per-second velocity needed for this is 11,700 metres," Newton remarked. "But please go on and describe your rocket."

"Go on, we're all ears!" the others exclaimed, Galileo loudest of all.

"Imagine an egg-shaped capsule. Inside the capsule is a pipe with an exhaust nozzle, accommodation for myself, and a stock of propellant explosives. When the propellants burn a gaseous jet escapes through the exhaust nozzle. The continuous burning of the propellant and the ejection of the combustion products with tremendous force generates a thrust force in the opposite direction which tends to propel the capsule upwards with mounting velocity. Three cases are possible: the thrust of the gas jet is insufficient to overcome the weight of the projectile; the thrust is equal to the weight of the projectile; and the

thrust is greater than the weight of the projectile. The first case is of no interest to us because the projectile won't move or it will fall back if not supported. The only result will be to reduce its weight. In the second case, it will lose its weight, that is, it won't fall if its supports are removed. In the third and most interesting case, the projectile will climb upwards."

"Using oxy-hydrogen gas," Laplace remarked, "it could hover in mid-air for 23 minutes and 20 seconds, if the weight of the propellant is seven times that of the vehicle and its payload."

"Quite right! But hovering in the air is of no use to us, so we won't consider that case. I'd only like to note that the apparent gravity inside the vehicle would not change, that is, all objects would retain their weights."

"You undoubtedly assume," Newton intervened, "that your gun stands vertically, muzzle downward?"

"Of course, though it could also be inclined to the horizon. But let us consider the third case. The greater the exhaust rate of the propellant, the better the performance of the rocket and the greater its acceleration.

"But then, firstly, the rapidly attained velocity will be lost due to the resistance of the air during flight through the atmosphere. Secondly, the gravity inside the vehicle will increase so much as to crush all living creatures inside.

"Furthermore," Franklin noted, "the gun would have to be very strong, therefore its weight would be too large, which is also a drawback."

"True enough. I think that a registered pressure ten times larger than the weight of the projectile and its load would be sufficient. In this case a person would feel only ten times heavier than usual. I have invented a device which will enable him to sustain this load with ease."

"It would be interesting to hear of this device," Helmholtz ventured.

"You shall, but in due course. To proceed. The projectile will move with acceleration. By the end of the first

second its velocity will be 90 metres a second and it will have climbed to a height of 45 metres. After two seconds its velocity will have doubled and the path travelled will have quadrupled. Let me draw a table showing the time, and the corresponding velocities and distances travelled by the projectile."

"I'll do it for you," Newton said, and wrote three rows of figures in large characters on a big blackboard:

Seconds	1	2	10	30	100
Velocities	90	180	900	2,700	9,000
Metres	45	360	4,500	40,500	450,000

"I don't approve of such a high rate of acceleration," Galileo remarked, studying the table. "True," he added after a moment, "in less than a minute the projectile will already be outside the atmosphere, but it will nevertheless lose much because of the drag. It would be preferable for the initial velocity, the velocity in the air, to be as low as possible. I would make bold to submit another table, based on tripled weight." He walked up to the blackboard and wrote the figures:

Seconds	1	2	10	50	100
Velocities	20	40	200	1,000	2,000
Metres	10	40	1,000	25,000	100,000

"In fifty seconds," the Italian continued when he had completed the table, "the projectile will have ascended 25 kilometres, where the resistance of the atmosphere is negligible, while the speed is still not too high. After escaping the atmosphere the thrust force and the acceleration can be increased, but in the air they should be kept as low as possible."

"Wonderful!" the Russian exclaimed. "Your remarks not only reveal your attention, but they are very useful as well. It goes without saying that I accept them with gratitude." Ivanov paused. "But now imagine the rocket shooting towards the sky. It moves slowly at first, then

faster and faster, till it disappears from sight and loses all connections with the Earth. . . ."

The others waited for Ivanov to continue, but he was silent. The lights in the hall had not been lit and a reddish Moon that had just risen cast a faint light. The Russian had fainted. Carried away by his idea, he had worked for several days without food or sleep and reduced himself to a state of extreme exhaustion. The lights were turned on and everyone leapt into action. Ivanov soon came round, but the others would not allow him to speak. Instead they made him drink some wine and eat a little food. They were all extremely excited, but for their companion's sake they refrained from discussing the subject.

It was decided to continue the discussion of what now interested them all on the following day. The Russian was left in Galileo's care, with instructions to build up his strength and get a good sleep.

4. MORE ABOUT THE CASTLE AND ITS INHABITANTS

While the castle and its inhabitants repose in slumber, let us find out more about them.

Two kilometres from the castle there was a waterfall which revolved turbines, which in turn drove dynamos, supplying an abundance of electricity. The current was transmitted by wire to the top of the hillock on which the castle stood. Electricity illumined all the rooms, performed all manner of chemical and mechanical operations in the workshops, provided heat when it was cold, ventilated, pumped water, and did a variety of other jobs which it would be too tedious to list. It was also used, incidentally, to prepare the supper with which our friends ended the day.

At night the castle was ablaze with electric light and presented a beautiful sight from afar, gleaming like a stellar constellation.

In the daytime, however, it was even more beautiful, with

its turrets and domes and terraces. It presented a charming sight against its background of sunlit hills. At sundown it glowed as if burning from inside.

The rugged environment was in keeping with the mood of the castle's inhabitants. They were all disillusioned, emotionally shaken people. One had lost a wife in tragic circumstances, another—his children, others had failed in politics or had been the victims of outrageous injustices or human stupidity. City noise and the presence of people only served to lacerate their wounds. On the other hand, the majesty of the surrounding hills, the eternally sparkling snow-capped peaks, the pure, transparent air, and the abundance of sunlight soothed and stimulated them.

All eminent scientists of world-wide fame, they were like thinking machines and, therefore, had much in common. Suffering and meditation had dulled their emotional susceptibility and elevated their minds. Affinity to science drew them together.

Their differences were not characteristic: Newton was more of a philosopher, a profound thinker and phlegmatic; Franklin inclined to pragmatism and religion; Helmholtz had made many discoveries in physics, but at times he was so absent-minded that he forgot which was his right hand; he was more of a choleric; Galileo was a zealous astronomer and an ardent art connoisseur, though for some reason he inwardly despised his passion for refinement; Laplace was mainly a mathematician, while Ivanov was a great dreamer, though possessing vast knowledge; more than the others was he capable of abstract thought, and it was he who most frequently broached such unusual subjects as the one discussed by our companions on the day described.

Contact with the outside world was maintained by huge metal dirigibles capable of carrying hundreds of tons of cargo at speeds of one hundred and more kilometres an hour. For small cargoes and few passengers aeroplanes were used.

5. FURTHER DISCUSSION OF THE ROCKET

The following evening the Russian continued his report.

"We see that in a few seconds the projectile will reach extremely rarefied atmosphere, and several seconds later will be travelling in total vacuum. Assuming the average thrust force of the gases to be ten times greater than the total weight of the rocket and its pay load, we find that, given the most powerful propellants, it will consume its entire fuel supply in 160 seconds. By then it will have risen to an altitude of 1,152 kilometres and attained a maximum velocity of 14,400 m/sec. This speed is sufficient to carry it away forever not only from the Earth, but from the Sun as well. All the easier will it be to reach any planet of our system. From what has been said you will undoubtedly also realise the difficulties of such an enterprise. We'll need air for breathing, but no means of getting it. . . ."

"We can take a supply of air," the Italian remarked. "True, it will soon be exhausted."

"But sunlight is capable, through the medium of plants, of purifying the air polluted by breathing," Helmholtz objected.

"In any case," the Russian said, "this problem will require a thorough study before it is put to practice. Now another question: how are we to return to Earth or land on another planet? A special reserve of explosives will be necessary if we hope to remain alive."

"For some time I've been experimenting on the problem of explosive energy," Franklin intervened. "I think I'll be able substantially to reduce the mass of the propellant by replacing conventional explosives by new ones."

"The best of success to you," the Russian commented. "Only by joint effort can we hope to put our plan into effect."

"In any case, it's far too risky," observed the cautious Newton. "You've forgotten about food. You can't travel long without food and water."

"I don't contemplate long journeys at first," Ivanov objected. "A trip to the Moon and back, for instance, can be made in a week. This disposes of the food question, at least in the initial stages. Several kilograms of food and water are of no consequence.

"And so, gentlemen," he summed up, "let us work together on the details of the project. Then we'll experiment with flights beyond the atmosphere at an altitude of about 500 to 1,000 kilometres."

"Later we can expand the scope of the experiments," Laplace remarked. "I wouldn't even mind being the first to fly, once everything is completely worked out, and I'm convinced the experiment is not dangerous."

Franklin smiled.

"Anyone would embark on the flight, given such assurances!" he said.

"We'll all fly together with Laplace," a chorus of voices echoed.

"But meanwhile," said the Russian, "it wouldn't be a bad idea to reproduce in vivid colours the picture of our trip. . . ."

"I'm a star-gazing enthusiast," said Newton, "and I'd be very happy, with your kind permission, to devote our evening leisure hours to a series of lectures, which could be attended by all the inhabitants of the castle who wished to."

The company decided unanimously that it was an excellent idea and directed Newton to lead their astronomical talks.

"But you mustn't forget," said Newton, "that your audience will include not only scientists: many other people in the castle will want to hear you, and some of them don't even know the difference betwen a star and a planet."

"Exactly," said the Italian. "Your lectures should be both interesting and popular. Maybe I'll be able to help you. . . ."

"And I, and I!" the others exclaimed.

"Thank you, gentlemen," Newton replied.

"We'll work during the day," Helmholtz said, "and in the evening we shall discuss the unparalleled event."

"When we have successfully concluded our work, we'll call a special meeting," Franklin suggested.

6. NEWTON'S FIRST LECTURE

At dusk the following day they all assembled in the round hall together with the several people from the castle who wished to attend the lectures.

Five of the scientists sat at the table, the others occupied soft couches along the walls.

"The planet inhabited by mankind," Newton began, "represents a sphere with a circumference of 40,000 kilometres. A person walking 40 kilometres a day would take a thousand days, or about three years, to circle it."

"The speed of modern steamships and railway trains," Franklin remarked, "makes it possible to reduce the time it takes to journey round the world twenty-four times. Actually, it is possible to average 40 kilometres an hour instead of a day and to circumnavigate the globe in 42 days."

"But what supports this enormous sphere?" one of the workers exclaimed.

"The sphere rests on nothing and is supported by nothing," Galileo replied. "It hurtles through the ether like a balloon driven by the wind.

"The globe is a double magnet. The first magnetism directs the magnetic needle of the compass; the second magnetism is called gravity. It is the latter that holds on to every object on the Earth's surface: the oceans, the atmosphere, people. If it were not for gravity, the air, thanks to its ability to expand, would long since have escaped from the Earth. Similarly, a single leap would carry a person away forever and make him a free body in the ether."

"What is this ether? Is it like the ether we have in our clinic?" another worker asked with a smile.

"Oh, no!" said Helmholtz. "It's something in the nature of air, only extremely elastic and rarefied. The nature of ether is still very much of a mystery.* It is a medium which fills the whole of space and through which light travels. Thanks to it we can see near and distant objects, if they are large and bright enough. Without it we'd be unable to see the Sun or the stars....

"...If we were to line up all the people on Earth one metre away from each other, they would girdle the globe 200 times."**

"Only? But I thought there were 5,000 million people on the Earth," someone remarked.

"Quite right," Newton said. "So you can imagine the immensity of the Earth compared with man, who rightly judges of the greatness of nature in relation to himself.

"If humanity were evenly distributed over the whole surface of the Earth, in hot and cold countries, on seas and lands alike, the closest neighbours would be more than one thousand metres apart. They would hardly be able conveniently to engage in conversation. The quantitative insignificance of man is even more striking: if his aggregate mass were pulverised and spread evenly all over the globe it would make a layer some 1/23,000th of a millimetre thick, i.e., one-thousandth the thickness of a sheet of tissue-paper."

"The slightest breeze would waft him away," an engine operator exclaimed.

"The Earth, man's heritage, is beautiful," Galileo inter-

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* Some scientists even deny its existence. See also K. E. Tsiolkovsky, *The Kinetic Theory of Light (The Density of Ether and Its Properties)*. Publication of Kaluga Society for Natural Studies and Local Lore, 1919.—*Ed.*

** The story was begun 20 years ago. Later, when I altered it to move the events 100 years away, I made the population 5,000 millions. The result was a discrepancy which I omitted to amend. (*The author's note was supplied in 1927.—Ed.*)

vened. "But if he were told: go and survey your domain, how long do you think it would take him?"

"We don't know," voices exclaimed.

"If he were to survey only the dry land, which occupies about one-quarter of the Earth's surface, and if it took him a second to inspect every hectare, it would take him 400 or 500 years!"

"I was sure that a lifetime wouldn't be enough to see the whole world," one worker commented.

"And you were right!" Newton said. "But imagine then how great the mass or volume of the Earth is! If someone were to knead the globe into spheres of equal size and give one to every person, including, of course, women and children, what would be the size of such a globule?"

"It would undoubtedly be a large chunk," someone ventured.

"It would be a whole planet 11.75 kilometres in diameter," said Laplace.

"Its surface would be 380 square kilometres," Newton added.

"Why, that's as much as a whole German principality," the Russian commented. "There would be sufficient elbow-room on it!"

"There are other ways of showing man's insignificance as compared with the planet," Newton continued. "Picture to yourself the Earth and everything on it reduced to the scale, say, of 1/10,000th. We would have a sphere 1,260 metres in diameter, and on it a pygmy 1/5th of a millimetre in height. And that would be the tallest inhabitant of the Earth."

"He could drown in a sea the depth of a grain of sand," Helmholtz added.

"The atmosphere would be 20 metres high and the tallest mountains only 85 centimetres. The oceans would be only slightly deeper."

"But that is sufficiently noticeable," someone remarked.

"Take a smaller scale," Galileo said, "and you would

discern neither mountains nor oceans. Picture the Earth as a ball 12.5 centimetres across, and the tallest mountains and deepest seas would be represented by uneven patches of 0.1 of a millimetre, the thickness of a sheet of writing paper."

"Which means that our globe is pretty well ironed out," joked a turner.

"Yes," Newton answered, "provided one travels far enough from the Earth for its apparent size to be 12.5 centimetres."

It was getting late and so they decided to separate until the following evening.

7. THE SECOND LECTURE

The sky was unusually clear when the population of the castle assembled for their evening talk. Although hardly an hour had passed since sundown, the sky sparkled with stars. There was no Moon: it rose late.

"See how many stars there are!" said the Russian, pointing to the sky which could be observed very well through the polished glass dome.

In good weather a portion of the ceiling could be opened. This was done now, letting in the pure mountain air which brought a pleasant coolness after the hot day.

"I wonder what the stars are made of," one man asked after staring at the sky for a while.

"Let us first discuss the Sun and Earth," Newton suggested. "Then we'll be able to understand what the stars are. The previous lecture gave us a fairly vivid idea of the tremendous bulk of the Earth. Now I want to give you an idea of the size of the Sun. The Sun is a fiery globe which could be made into 1,280,000 fiery globules the size of the Earth."

"Some globules!" one of the listeners observed.

"But why does it seem so small?" another asked.

"Because of its terrific distance from us," Galileo answered. "It is 150 million kilometres distant from the Earth."

"And yet at that distance it can feel so hot!" someone exclaimed incredulously.

"That is hardly surprising, if we take into account its size," Newton replied. "Its diameter is 108 times that of the Earth. So if we pictured the Earth as a ball 12.5 centimetres across, the Sun would be a sphere 14 metres in diameter, the height of a five-storied building! But in spite of the difference in their volume, the Earth and the Sun are, in effect, almost identical. . . ."

Galileo interrupted him. "I'm afraid you're exaggerating," he said.

"I know," Newton replied. "My listeners haven't quite understood me."

"It does seem strange," one of the men said. "The Sun is an immense burning-hot body while the Earth is a comparatively tiny cold, dark ball."

"That's so, but not quite," Newton remarked. "The thing is that this little ball is still terribly hot inside. There was a time when the Earth sparkled and shone like a little sun, and the time may yet come when the Sun will cool down like the Earth."

"God forbid," the listeners sighed.

"The Earth is a tiny cooled sun, while the Sun is an enormous Earth which hasn't cooled yet only because of its size."

"Impossible!" the listeners exclaimed.

"Yet this is not only possible but quite obvious," the lecturer observed. "Firstly, the Earth still retains its internal heat. Secondly, what, in fact, is soil, what are granites and the overlying sedimentary rocks? They are all products of the combustion of metals, gases and metalloids. The Earth is covered with ash and is composed of ash. This all points to the huge conflagrations which once raged on Earth. Gases burned, and the purest metals and metalloids burned."

"And the very water of the oceans," Galileo interjected, "is merely a product of the combustion of hydrogen in oxygen. We are surrounded with ash: the rocks are ash, water is ash, the mountains are ash. The incombustible remnants are negligible. They exist, but are concealed in the depths of the Earth and are inaccessible to us. Man tries to extract his incinerated property from the ash inherited by him. He mines gold, silver, iron, aluminium and many other things for his needs, but how paltry are his gains!"

"As for the Sun," Newton continued, "it will continue to glow for a very long time, yet there already appear on its surface huge cinders the size of the Earth, and many scientists think that one day the Sun will be extinguished."

"How awful! When will that happen?"

"The demise of the Sun will occur in at most several tens of millions of years. . . ."

"Oh!" the audience sighed with relief, "that means neither we nor our children have anything to fear."

It had grown quite dark. The air was pure and countless stars twinkled overhead.

"All those stars are actually suns," Newton said. "Enormous, blazing suns not inferior to the luminary which sustains organic life on our Earth."

"And I thought there was only one Sun," a fitter remarked with naive surprise.

"If you undertook to count the stars, you would count not more than five thousand suns."

"But why does the number of stars on a dark night seem infinite?" the listeners asked.

"We feel this instinctively," the Russian said, "and our impression is not wholly unjustified."

"Precisely," Newton confirmed. "The better the glass at our disposal, the more stars can we see. The best telescopes reveal as many as 200 million stars. . . ."

"Two hundred million suns!" several voices repeated. "Incredible!"

"You will realise the magnitude of this number if instead of every star visible to the naked eye you imagine 40,000 suns, that is, eight times more than are immediately apparent in both hemispheres of the sky."

"In which case," Laplace put in, "we would have 10,000 stars on a patch of the sky the size of the Moon, and each of them would be a distant sun."

"Look at that bright red star," an engine operator exclaimed. "That must be a terribly big sun."

"Why, that's Mars," Galileo said. "A paltry planet like the Earth, one of the tiny cooled suns that we call planets. It is not self-luminous, like fire, and shines only thanks to the reflected light of our Sun. It is brighter than the stars because of its nearness to the Earth: the mere 70 million kilometres separating us is nothing on the scale of interstellar distances."

"Are there many such planets among the true suns?" asked a listener from the seats by the wall.

"There are seven planets visible to the naked eye in both hemispheres of the sky. In telescopes more than 600 can be observed. The seven big ones are called planets, the others, planetoids."

"Is that all?" someone asked incredulously, "considering the multitude of stars that is rather strange."

"You forget their small size and their obscurity," Galileo said. "That is why we see so few of them. We can see only the nearest planets belonging to our solar system and travelling round the Sun like the Earth, the eighth major planet. If our Sun has more than 600 planets, we may well assume that other suns have planets, too. But how can we see them if the enormous distances make suns themselves nothing more than glimmering pinpoints! Most of them can't be seen at all."

"Assuming," Galileo said, "that each sun has an average of at least 600 planets—for our Sun is no better than any other—the total number of planets should be not less than 80,000 millions."

"Which means," Laplace remarked, "that every person could receive a gift of 16 planets, some of which would be larger than the Earth.

"But who is to guarantee that with our weak eyes and our puny instruments, we see all the actually existing stars? If we see 200 million suns and presume the existence of 80,000 million planets, what, then is the number of suns and planets invisible to us?"

The population of the castle used the French language for communication. At first there had been a violent controversy over the common tongue to be used, but it was finally decided that it should be the simplest and most concise. An investigation was carried out, and French was found to meet the requirements. All mute letters were discarded and a phonetic orthography was introduced with each sound being written just as it is pronounced.

8. ATMOSPHERIC ROCKET TESTS

The lectures were discontinued for a while because our scientists were completely absorbed in the Russian's project.

Franklin invented a propellant 100 times more efficient than anything known. Recurrent blasts shook his laboratory and piercing hissing sounds and screaches often frightened the peaceful inhabitants of the castle. Newton and Laplace were engaged in endless computations. They wrote long rows of figures and formulas, whispered mysteriously and meaningfully together, sometimes ejaculating loudly as if in heated argument. Helmholtz worked on problems of life in ethereal space and elaborated breathing and feeding systems.

The Russian consulted one or the other and drew blueprints and travel plans. Galileo was all eagerness, and together with Ivanov he worked on a model of a celestial vehicle. There were setbacks at first and they had to go

from models back to drawings and computations, then on again to models. A month passed in this manner. They met in the glass hall daily, but outsiders were not allowed in.

The day finally came when our scientists brought their researches to a happy conclusion.

Everything was abustle in the workshop where the strange vehicle, in which our companions planned to visit the Moon, was being assembled. They decided to test the projectile in a high shed where it was held securely to a frame. Let us follow our companions into the well-lit shed and have a look at their vehicle and the experiment.

The vehicle was a 20-metre long cigar-shaped metal structure 2 metres in cross-section standing on end. Numerous portholes let in a sufficient amount of light. Three pipes ran down along its walls, protruding at the lower end. There were many mechanisms partially shielded by metal casings and large tanks of strange liquids. When mixed they produced a continuous, uniform blast the products of which escaped with tremendous force through the pipe nozzles in the lower part of the projectile. A row of knobs and numerous dials were intended for steering the projectile and varying the thrust. The other parts will be described in due course.

Franklin, Ivanov and Galileo entered the vehicle, while Laplace, Helmholtz and Newton retreated to a safe distance, where they kept glancing from their watches to the projectile. An explosion thundered forth followed by a deafening roar. The vehicle shuddered and rose as high as its tethers would allow. The spectators outside shouted something, their eyes sparkling, but words were drowned by the noise. Ten minutes passed and the party inside contacted their companions by telephone and congratulated them on the success of the enterprise. The experiment went on. For another ten minutes the rocket continued to hover and then slowly descended. Ivanov and Franklin climbed out and without a word threw themselves into

the arms of their friends. They were followed by the tardy Italian, who declared that only 1/100th of the propellant taken for the experiment had been expended.

The next test—of the controllability of the projectile—had to be conducted in public, which was inconvenient in the cramped space of the shed.

It was decided to set the vehicle up in the courtyard and observe its manoeuvres there. This time the Englishman, German and Frenchman boarded it. The spectators gathered a short distance away, behind a low fence surrounding the projectile, which gleamed in the sun like a mirror. Many were not aware of the actual purpose of the rocket and thought that it was only for meteorological research in the upper layers of the atmosphere.

The three friends took their seats inside and nervously awaited the time scheduled for the flight. Helmholtz shivered slightly; tense silence reigned. Newton had his hand on the lever controlling the rate of combustion and the thrust generated by the ejected gases. Laplace was to steer the rocket, while Helmholtz looked on, ready to replace either of them in case of need.

The long-waited moment arrived, and Newton shifted the lever. Laplace had set his lever in advance, and the projectile began very slowly to climb.

"Gentlemen, the rocket is behaving excellently," Helmholtz exclaimed joyfully. It was all he could do to retain his composure. "We've climbed 100 metres. Now stop the motion!"

Newton shifted his lever and the rocket stopped moving, although the gases continued to escape with tremendous force. After a few seconds of hovering flight Newton suggested that they accelerate their upward motion, in which case their apparent weight inside the vehicle would double, i.e., each would weigh from 128 to 160 kilograms. The safety of this test had been established in the course of the preliminary research. His companions had no objections, and they sat back more firmly in their seats. New-

ton moved the lever. They all grew pale. The cushioned seats sagged beneath their increased weight.

"Gentlemen, I can't stand any more," Laplace pleaded after 20 seconds. "That's enough, please!" he entreated looking up comically from the depths of the seat into which his increased weight had pushed him. Newton turned the lever to end the test with a hand weighted down by the increased gravity. When they felt well again they all hastened to their feet and peered out of the portholes.

"We've flown the devil of a distance away," Helmholtz remarked with annoyance. The castle and surrounding buildings could hardly be seen in the distance.

"Not the devil of a distance but only two kilometres," Laplace remarked, glancing at the barometer.

"If we had taken precautions about breathing," said Newton, "in ten minutes we could have risen to an altitude of 1,800 kilometres. But now we must think of returning immediately, otherwise in several seconds we'll suffocate in the rarefied atmosphere, for the rocket is travelling at a rate of 200 metres a second."

While Newton spoke they had climbed another kilometre and began to gasp for air. Newton stopped the burning of the propellant. At the same instant they lost their weight, each becoming lighter than a speck of dust. It was a curious sensation, but as they continued to coast upwards and had to struggle more and more for breath they had no desire to make observations. After climbing another two kilometres the vehicle stopped as if uncertain of the course to follow and began to descend exclusively under the force of gravity. The state of weightlessness continued, but after 20 seconds the rocket's fall was retarded, and several seconds later a series of blasts brought it lightly to rest on its pad in the castle courtyard. During those 20 seconds they were again pinned down to their seats by the increased weight.

9. ANOTHER ASTRONOMICAL LECTURE

Our scientists' success was complete and they decided to undertake a flight beyond the atmosphere.

They marked the occasion by gathering in the round hall for a third lecture at which they informed the public of the vehicle for flight in ethereal space.

After briefly describing the projectile, Newton said:

"Now, with the promise of interplanetary flight, astronomy should be of special interest to us. We learned at our previous lectures that the visible universe of stars, or suns, contains not less than 80,000 million planets. In our own solar system we know for sure of the existence of over 600 planets. In view of our forthcoming journeys, it would be interesting to consider the distances of the planets from the Sun and the Earth. Can we cover these distances? Moreover, is a human life long enough to undertake such journeys.

"Our closest celestial neighbour is the Moon. The Moon is a child of the Earth, just as the Earth and the six hundred other planets, including the major planets, are children of the Sun."

"Which means," a voice from the audience remarked, "that the Moon is a grandchild of the Sun."

"Exactly," Galileo agreed. "But the Sun has many other grandchildren as well: the moons of other planets. Jupiter, for example, has eight moons, eight children, and all of them, like our Moon, are grandchildren of the Sun."

"Let us discuss the Moon," Newton continued. "It is 380,000 kilometres from the Earth. Travelling in our space vehicle at an average of five kilometres a second, we could reach it in 76,000 seconds, that is, less than a day."

"There's the Moon rising," said one of the listeners. "One could probably fly to it in a balloon or an aeroplane. . . ."

"Yes," Ivanov replied, "if the atmosphere extended that high! But even then it would take a thousand days, or about three years, because we can't travel in air as fast as in a vacuum."

"The atmosphere, however," Laplace remarked, "envelopes the Earth like the skin of an orange, i.e., to an insignificant height. It is very light, diaphanous attire."

"The atmosphere extends to an altitude of 300 kilometres," Franklin went on to explain. "But at a height of ten kilometres it is already so rarefied that a man is unable to breathe and would inevitably perish.

"At the very most, the atmosphere reaches to not more than 1/1,000th of the distance to the Moon and, naturally, it can't be used for flying to the Moon in a balloon."

"Is that so!" the same listener exclaimed. "I always thought that not only the Moon but the stars, too, were floating in our atmosphere."

"The stars are too far away!" another listener remarked.

"Yes," Newton confirmed. "The nearest star is our Sun, and it is 150 million kilometres away. You can imagine how far off the other suns must be if we see them as mere glittering specks though some of them are actually much brighter than the Sun."

"Flying in our vehicle at a speed of 10 kilometres a second," Franklin said, "we could reach the Sun in 15,000,000 seconds, or less than half a year. The distance to the planets of our solar system can also be expressed in terms of years and, if we discount difficulties other than time, it would be quite feasible to reach them in our vehicle."

"The planets of other suns, however, are inaccessible to us," Helmholz remarked. "The human span of life would be too short to reach them in."

"In fact," the Russian said, "the second closest star (α) of the constellation Centaurus, is 38,000 million kilometres away. It would take about 12,000 years to cover this distance, even travelling at 100 kilometres a second, which is a feasible speed. If a large company embarked on such a journey, only the four-hundredth generation would arrive at that sun."

"What a pity," Galileo exclaimed, "that those 80,000

million planets which Newton mentioned are forever inaccessible to us!"

"Indeed it is," said Ivanov, "but don't forget that humanity is immortal and 12,000 years is nothing to it. So even if those suns and planets are not *our* inheritance, they may become the inheritance of mankind as a whole."

"And yet," Newton observed, "the Sun with its planets and their satellites are more important to us, for we can settle them while we can only dream of other suns and their planets. Here is a scale model of our planetary system. The scale is 1/1,000,000,000th. Imagine a fiery sphere 139 centimetres in diameter—the Sun. Revolving round it in approximately the same plane are the planets and their moons. The nearer to the Sun the greater their speed. The nearest and fastest is Mercury. In our model it is shown as a ball five millimetres in diameter (a small pea) and 58 metres from the Sun. Next comes Venus, represented by a 12-millimetre ball (the size of a hazelnut) 105 metres from the Sun."

"And there's Venus itself," Galileo interrupted, pointing to the West where a bright star gleamed in the gathering dusk.

"Venus shines brighter than any other star," Laplace remarked.

"I once even observed it in daytime, when the Sun was shining," said Franklin. "Mercury and Venus can be seen either in the West or in the East. Mercury is the more difficult to observe because it is very close to the Sun and sets almost immediately after it."

"Let us continue," Newton said. "After Venus, at a distance of 148 metres from the central body, we have the Earth, a nut 13 millimetres across."

"At last!" one of the listeners remarked. "You've reduced the Earth almost to the other planets."

"It was not my intention to belittle the Earth," Newton replied. "That is how nature has made it and you'll have noticed that it is larger than the first two planets. The

next planet is Mars, represented by a pea 6.5 millimetres in diameter. It travels more slowly than the Earth because it is farther away—227 metres. Look there! See that bright red star in the East? It has already risen fairly high. That's Mars. It has two satellites, tiny specks too small for our scale, which circle it with terrific speed and at the same time travel about the Sun together with their primary."

"You've forgotten the Earth's Moon," Laplace broke in. "The Moon is the most accessible to us, and therefore the most interesting body. Our exploration of celestial bodies will start from the Moon."

"That's so," Newton agreed. "Our Moon is represented by a millet seed 3.5 millimetres across and 38 centimetres from the Earth. It revolves round the Earth and together with it round the Sun, like the other planets and their satellites.

"Beyond Mars we find more than 600 planets represented by tiny poppy seeds and specks of dust. They vary widely in size but all are very small. They form a rather tightly packed belt, which, however, doesn't prevent them from moving uniformly in one direction around the Sun. Beyond this swarm of planets we find the largest planet of all, Jupiter, represented by a big apple or a small melon 14 centimetres across. The Earth looks puny by comparison, for we could make 1,390 terrestrial globes from the material of Jupiter.

"It's the biggest planet, and in our scale it will be 750 metres from the Sun. It has eight satellites the size of millet and poppy seeds."

"The nearest one," Laplace remarked, "is a speck of dust."

"And with this planet," Newton said, bowing to his audience, "allow me to end my narrative."

Everyone thanked the lecturer and, after wishing each other good night, they separated.

The lectures, however, were discontinued: our scientists were so engrossed in their space vehicle that they lost interest in instructing their audience in the celestial sciences. They decided to carry out a flight beyond the atmosphere as soon as possible. The vehicle was hermetically sealed and filled with pure oxygen (without nitrogen) to one-tenth of atmospheric pressure, or half the pressure of the oxygen of the air. This made breathing easy while at the same time avoiding the overstimulation produced by the inhalation of oxygen of atmospheric pressure. Furthermore, the low internal gas pressure enabled the rocket hull to be made comparatively thin. It was planned to take a large stock of substances, by mixing which oxygen could be produced. Carbon-dioxide and other human refuse would be absorbed in the vehicle by alkalies and other preparations, thus continually purifying the atmosphere of the capsule polluted by breathing.

The daily requirement per person of these substances for breathing purposes was about 10 kilograms.

Since in the unusual flight conditions a person might easily lose his presence of mind and fail to operate the necessary controls, it was decided to develop an automatic pilot which would shift the various switches at the required time and steer the rocket at the correct speed and in the right direction.

By common consent it was decided to feed the following instructions into the automatic pilot: the rocket would take off parallel to the plane of the equator at an angle of 25° to the horizon in the direction of the Earth's rotation. During the first 10 seconds its velocity would increase rapidly to 500 metres. In passing through the atmosphere the rate of the acceleration would be low until the air was sufficiently rarefied. With the Earth's atmosphere left behind the velocity would again increase rapidly, the direction of flight gradually changing until, at an altitude

of 1,000 kilometres, the rocket would enter into circular orbit. The speed at that point should be such as to keep the vehicle in a circular path about the globe without approaching it. The automatic pilot, of course, could be switched off or reset.

11. ETERNAL SPRING. THE COMPOUND ROCKET. PREPARATIONS AND SUPPLIES

Time flew swiftly. There was much work to be done, many tests to be carried out and there were many more setbacks. Much time was spent on improving the injector, a device for feeding the two liquid propellants into the combustion chamber, where they exploded on contact. The temperature was enormous, and it was hard to find materials which would be both refractory and durable. Ordinary pumps were unsuitable because they required a high driving power, and consequently an engine capacity which the rocket did not possess. A possible design was that of a Giffard steam-jet pump (injector) in which the work was done by the propellant itself. Unlike conventional rockets, their projectile required an injector. In conventional rockets the pressure of the combustion gases acts on the propellant storage tanks, which therefore have to be thick-walled and very heavy. When the propellant supply is small a rocket can climb and fly even with heavy tanks. With an enormous propellant supply the tanks had to be relieved of pressure to reduce their weight. This could be achieved only if pumps or injectors were employed. During the initial tests, when the flights were of short duration, it was possible to do without them. It was also necessary to find suitable materials for the exhaust pipes, the rocket skin and other parts. Much time went into perfecting the controls, the temperature and air-breathing regulators, etc. At long last the date was fixed for a flight beyond the atmosphere, round the Earth.

At an altitude of three or four kilometres the sultry climate of tropical countries, which is so oppressive in lowlands lying close to sea level, turns into eternal spring, with its mildness, sunlight and stable weather conditions. This was the sort of the locality where our anchorets lived. There were very many clear days and an abundance of light, the air was dry and the temperature even, generally 10-15°C lower than at sea level. The temperature ranged from 10 to 20°C in the shade during the day-time, dropping considerably at night. But then, at night they hardly ever worked in the open, preferring to find jobs indoors, where it was warm. Thanks to perpetual spring, people could work all the year round in the shade of trees or awnings. They had to shield themselves from the sun, for it was much more intense than down in the low valleys, and more liable to produce a sunstroke.

* * *

From the simple rocket they proceeded to the compound rocket made up of several simple ones. The complete set-up represented an elongated, streamlined body, 100 metres long and 4 metres across and resembling a mammoth spindle. It was divided by lateral partitions into 20 sections, each of which constituted a self-contained rocket-propelled apparatus, i.e., each section carried a supply of propellants, a combustion chamber with a self-operating injector, an exhaust nozzle, etc. There was a middle section which had no propulsion motors and served as a compartment. It was 20 metres long and 4 metres in diameter.

The injectors were designed for continuously feeding the propellants at an even rate into the combustion pipe, and they were similar in operation to Giffard's steam injectors. The compound-rocket construction made it possible to achieve comparatively low weight combined with tremendous thrust. The combustion pipes formed coils which expanded gradually towards the exhaust nozzle. Some of the coils wound athwart the rocket, others were

wound longitudinally. By revolving in two mutually perpendicular planes the exhaust gases gave the rocket greater stability. It did not yaw and pitch like a poorly guided vessel but flew straight as an arrow. The exhaust nozzles, which projected along the sides of the rocket, were all pointed in almost the same direction, forming a spiral about the circumference of the rocket.

The combustion chambers, injectors and exhaust pipes were made of extremely refractory and durable substances, such as tungsten. A motor was encased in a chamber through which flowed one of the propellants. The evaporation of the liquid kept it sufficiently cool. The other liquid was kept in isolated tanks. The rocket skin consisted of three layers. The inside layer was of a strong metal, with portholes of quartz covered over with a layer of ordinary glass, and air-tight doors. The second was a refractory layer with very low heat conductivity. The outside layer was a fairly thin but very refractory metal shell. During the rocket's acceleration through the atmosphere the external shell would heat to a white glow, but the heat would be radiated into surrounding space without penetrating inside. Inward radiation was prevented by a gas coolant continuously circulating between the outside and inside layers through the porous, low heat-conductive middle layer. The thrust was controlled by a complex system of injectors. The combustion could be started or stopped at will. These and other devices made it possible to change the direction of the exhaust and the orientation of the rocket's axis.

The interior temperature was controlled by a system of valves regulating the flow of the gas coolant through the middle layer of the rocket walls. Oxygen for breathing was supplied from special reservoirs. Other devices were designed for absorbing the waste products of the skin and lungs, and they too could be adjusted to suit the passengers' needs. There were compartments containing supplies of food and water. There were special suits to be worn

for emerging into vacuum space or the hostile atmosphere of strange planets. There were numerous general- and special-purpose tools and instruments. There were tanks of water to accommodate the travellers during periods of increased relative gravity. Submerged in the water, they were provided with special breathing pipes protruding into the rocket's atmosphere. The water offset any increase in weight during the short period of acceleration. In such a tank a person could move his limbs as freely as on Earth without any sense of burden, like a swimmer or like the olive oil in wine in Plato's experiment. This ease and freedom of motion made it possible to operate all the rocket controls freely, to keep control of the temperature, thrust force, direction of flight, etc. For this, levers and switches were submerged in the water. Furthermore, there was a special automatic pilot which could operate all the rocket controls for several minutes. During that time there was no need to look after the controls, which operated by themselves according to commands fed to them in advance. The supplies included seeds of various fruits, vegetables and sereals to be planted in special greenhouses which would be erected in outer space from prefabricated structural elements.

The volume of the rocket was about 800 cubic metres. It could have carried 800 tons of water. Less than a third of this volume (240 tons) was occupied by the two liquid propellants discovered by Franklin. This quantity was sufficient for 50 accelerations of the rocket to the velocity required to escape from the solar system forever and for 50 corresponding decelerations. Such was the propulsive power of the fuels. The rocket proper with all its accessories weighed 40 tons. The supplies, instruments and greenhouse elements weighed 30 tons. The passengers and everything else weighed less than 10 tons. Thus, the weight of the rocket and the pay load was one-third of the weight of the propellants. The living quarters, i.e., the sections filled with rarefied oxygen, occupied a volume of about 400 cu-

bic metres. It was decided that 20 people would embark on the flight. Each would be provided with 20 cubic metres of living space which, with the atmosphere being continually purified, was quite adequate. The 21 compartments were connected by small passages. The average volume of each compartment was about 32 cubic metres, half of which was occupied by the necessary furnishings, equipment and the propellants, leaving 16 cubic metres of free space. The middle compartments were larger and provided excellent quarters for one person. One compartment in the broadest section of the rocket was 20 metres long and served as a drawing-room. All the compartments had portholes provided with inside and outside shutters.

12. ATTITUDE OF THE OUTSIDE WORLD. LOCATION OF THE ROCKET

The outside world had been totally unaware of our scientists' plans. The newspapers had kept silent, and the scientists had said nothing. These events took place in the year 2017. But even then there were secluded places, remote nooks from which hardly any news leaked to the greater world. The whole population of the community consisted of the personnel, workers and associates of the scientists, and none of them cared for publicity.

The rocket site was not far from the castle, on a slope with a gradient of 25° or 30° to the horizon. It was open to observation from airships and aeroplanes which often carried cargoes and passengers over the area. In many respects it was like the case of the Wright brothers more than a century earlier: Europe and the world began to believe in them only after two years, and although many train passengers had seen the brothers flying their aeroplane, people had refused to give credit to the stories of eyewitnesses.

13. THE SEND-OFF. LOCKED IN THE ROCKET. THE DEPARTURE. FIRST IMPRESSIONS

Newton, Laplace, Franklin and Ivanov were chosen for the flight. The crew also included 16 workers handpicked to perform all the duties required to man the rocket. The whole community came to see the travellers off. Long before launching time a crowd surrounded the rocket. The weather was fine and the sun shone brightly. True, there was nothing extraordinary in this as it was the usual weather for the locality. The air was dry, crisp and invigorating. The dryness of the region made it necessary for the castle's inhabitants to irrigate their fields, orchards and gardens. There were many waterfalls and rapid mountain streams from which water was diverted to the orchards and cultivated fields. The rocket stood amidst attractive fruit trees, and stately sequoias towered a short way off. Good wishes and embraces were exchanged and to the excited shouts of the crowd all twenty travellers boarded the rocket. They sealed the openings hermetically and switched on the electric lights. The double shutters were drawn and the men submerged themselves in the water tanks. They breathed through the breathing pipes and could move their hands freely and steer the vehicle with the help of levers submerged in the water. Newton's job was to control the thrust in the exhaust pipes; Laplace was to steer the rocket and also to neutralise any rotational motion that might appear; Franklin looked after the air conditioning; Ivanov looked after other things and everything. He could communicate with his companions, and they among themselves, through a system of voice pipes. The other sixteen men could only inform one of the head-workers of their needs, the latter, if necessary, passed the information on to Ivanov. This time Ivanov was elected to supervise the flight.

"Gentlemen," he inquired. "Can we start our flight? Is everything in order? Are you all ready?"

Everything was reported to be in order and the passen-

gers ready. Ivanov shifted a lever, as he had done before. A series of blasts could be heard which soon turned into a monotonous deafening roar. The passengers' ears were protected by the earpieces and the layer of water, otherwise their eardrums would not have withstood it. Electric light penetrated through small windows in the coffin-like tanks where our friends lay submerged in water. The "deceased" were lively enough, however, and they looked about them unperturbed, examining the familiar walls of the rocket and the cabinets and instruments which they themselves had attached.

"Gentlemen," Ivanov informed them, "the relative gravity is now ten times greater than terrestrial gravity. Some of you now weigh 650 or 800 kilograms. Do you feel the difference? Does anyone feel any pain or discomfort?"

"All is fine! An excellent bath! Complete relaxation! No change in weight! Complete freedom of motion! Simply wonderful!" a chorus of reassuring and even happy voices responded.

Several seconds passed.

"It's hot, the breathing air's too hot!" one rather stout worker complained.

Ivanov passed the complaint on to Franklin who turned a switch to accelerate the circulation of the gas coolant. The temperature dropped.

Several more seconds passed.

"It's getting cold," someone complained.

This was also rectified. All complaints were immediately dealt with: at one point it became hard to breathe because of the accumulation of carbon dioxide; then the rocket began to rotate about its longitudinal axis and the weaker passengers felt giddy. No one complained, however, when there was an excess of oxygen, but this was not allowed just as drinking is not allowed, even though it enlivened everybody.

The thrust was not constant, since considerations of economy in regard to the propellants—their energy reserve

—called for a strict, previously computed sequence of gas pressures to be maintained. This was effected automatically. As a result the relative gravity changed continually. No one noticed this, however, nor could they have done, thanks to the water in which they were submerged, which had the same density as the average density of their bodies. Only several poorly secured objects fell off the walls. However no one heard them fall because of the roar and din of the rocket motors.

14. ON THE EARTH. LECTURES IN THE CASTLE

Let us leave our companions to continue their flight and return to the castle's inhabitants who had gathered to see them off. The crowd saw the rocket lurch forward and gather speed at an angle to the horizon. Many started back in fright. All were deafened by the roar, but it subsided rapidly as the rocket climbed higher and higher, heading towards the east, in the direction of the Earth's rotation about its axis. In ten seconds it had covered five kilometres and was travelling with a spead of 1,000 metres per second. It could hardly be seen through a powerful field-glass, and then only thanks to the fact that it had begun to glow from air friction. Actually it disappeared from sight almost instantaneously. A deafening roar mounted steadily and then grew weaker. Peals of thunder continued to shake the air even when the rocket had disappeared from sight. The people looked up for clouds, but the sky was clear. The thunder was caused by the atmospheric wave produced by the rocket cleaving through the air.

Helmholtz and Galileo invited everyone to the assembly hall where they could relax and talk. Some took armchairs, others occupied seats forming an amphitheatre. Fruit and soft drinks were served by way of refreshment. There was a buzz of conversation, as people discussed the rocket and its passengers.

Galileo suggested that they discuss the event. The

people made themselves comfortable and the hubbub subsided.

"Gentlemen," Galileo began. "I should like to give you an idea of how our friends must have felt in the rocket. I've overheard some of your arguments and I find that many of you are wrong. Let us assume that acting on the rocket—the rocket alone, but not the bodies in it—there is a constant force in one direction, for instance, the thrust. Assume, for a moment, that the gravitational attraction of the Earth and other celestial bodies has disappeared. The thrust force will propel the rocket with uniform acceleration, i.e., the velocity will increase in proportion to the time. Anybody inside the rocket not touching the walls or floor will seem to be falling in the opposite direction of the external force acting on the rocket. Thus a body will seem to be falling with uniform acceleration. If a floor, table or any other obstacle restricts this motion, the falling body will press against it. This pressure will be equal to the apparent weight, the action of which in no way differs from weight due to the attraction of a planet. The magnitude of this apparent weight will be greater, the greater the per-second increase in the rocket's velocity. The acceleration of the free fall on Earth is approximately 10 metres per second. If an external force imparts to the rocket the same acceleration, the weight of an object inside will be the same as at the surface of the Earth. If the per-second acceleration is ten times greater, the apparent weight inside the rocket will also be ten times greater than on Earth. This artificial gravity, as I have remarked, will be directed opposite to the force acting on the rocket."

"What effect have the Earth, the Sun and the planets on the apparent weight inside the rocket?" several voices asked.

"I shall now proceed to explain this," Galileo replied. "Let us consider, for example, the effects of the Earth's gravitational attraction.

"The Earth's gravity acts not only on the rocket but on all the objects in it as well. If the rocket moves in any

direction under the influence of this all-penetrating force, any object inside or near the rocket subjected to the action of the same force will move in a similar way. An observer inside the rocket will see no difference between the motion of the rocket and the objects about it. Thus, the effects of the Earth's gravity can't be observed in relation to the rocket. We therefore conclude that neither the Earth nor any other celestial body has any influence on the apparent gravity inside the rocket, i.e., they can neither increase nor diminish it. This, of course, holds good for rectilinear, uniform, all-penetrating forces."

"Consequently," Helmholtz said, "the apparent gravity inside a rocket depends only on the acceleration caused by the exhaust gases ejected from the nozzles. If the per-second increase of velocity (or acceleration) is 100 metres all objects inside the rocket will be 10 times heavier than on Earth. The Earth, Sun and planets, for their part, don't affect the apparent gravity."

"From this, it can also be concluded," the Italian remarked, "that when the combustion of the fuel is stopped and the rocket is no longer accelerated by the pressure of the exhaust gases the relative gravity will disappear completely, regardless of the magnitude of the all-penetrating gravitational forces. The crew will then float in their atmosphere, neither falling nor pressing against the floor or obstacles. They'll be like fish in water with the advantage that they won't have to overcome the great resistance of water when they move."

"What a wonderful state," several voices exclaimed.

"I have a question," one of the listeners said. "When the rocket leaves the atmosphere there will no longer be any external pressure acting on it. Won't the elasticity of its internal atmosphere explode it?"

"The rocket's walls can stand a pressure one hundred times greater. Besides, the rocket is filled with pure oxygen of one-tenth the density of the atmosphere. Its elasticity is one-tenth that of air, and the partial pressure is

half that of the oxygen of the atmosphere. Thus the pressure on the walls will be one-tenth of normal atmospheric pressure. This is too small to damage the rocket."

"Isn't there a danger of developing a haemorrhage in such a rarefied atmosphere?" a worker asked.

"The effects of such an atmosphere were successfully tested during the preliminary experiments," Helmholtz said. "But if the crew experiences discomfort they can make their gas medium denser by adding as much nitrogen as they want to."

"Just one question about the temperature," asked a very young man. "The temperature of outer space is very close to absolute zero, or 273°C below freezing point. Can people stand that temperature?"

"The temperature of space is determined by means of a thermometer," Helmholtz explained, "and what we actually do is to determine the temperature of the thermometer. In the absence of any celestial or terrestrial radiating bodies, the thermometer like any other isolated body loses all its heat through radiation, ultimately cooling down to absolute zero, or 237°C below freezing point."

"We don't even know what might happen to a body in such an event," Galileo remarked. "Its properties may change completely. Its internal cohesion may increase indefinitely and it may contract tremendously even to the point of disappearing altogether."

"Yes," Helmholtz agreed, "it's difficult even to imagine what might happen to a body in such conditions. But ethereal space is filled with a variety of vibrations, and electrons and many smaller particles of matter move violently in it. This is caused by the radiation of the Sun, planets, Earth, and the ether itself. In practice, therefore, the atoms of a thermometer or any other body can't stop moving and a body can't lose all its energy. We can neglect the radiation of distant suns, or stars, and of the planets, which is negligible compared with that of the Sun. Our rocket, flying some distance from the Earth, will be almost

constantly subjected to solar radiation. The question is, to what temperature can this radiation heat the rocket?"

"That depends not only on the distance of the body from the Sun," said Galileo, "but on its shape, colour, motion, and other factors."

"Precisely," Helmholtz assented. "The scientist Stefan developed a law by which to determine, at least approximately, the temperature of planets and other even very small bodies subjected to different conditions. According to his law, a plate perpendicular to the Sun's rays at the distance of the Earth, with the side facing the Sun covered with carbon black and the reverse side prevented from losing any heat should be heated to 152°C. This is the maximum possible temperature on Earth, and we might expect such temperatures on the Moon. If we had a revolving dark ball, its mean temperature would be 27°C. The same could be achieved with a rocket painted black, and if its shaded side were prevented from radiating heat and given the right shape its temperature could reach 152°C. If the ball isn't black and reflects an appreciable quantity of heat back into space, its mean temperature will be lower. Thus, in the conditions of the Earth, which reflects 20 per cent of the Sun's rays, the temperature would be 13°C (the mean temperature of the Earth reduced to sea level is 15.5°C)."

"That's all very well," one of the workers objected. "But what will it be like in the rocket at the distance from the Sun of, say, Mars? Won't the passengers freeze to death then?"

"The answer is best supplied by figures," Galileo replied. "Even twice as far from the Sun as the Earth, the maximum temperature of a black plate is 27°C above zero. By using different means to prevent radiation from the shaded side of the rocket and facilitating the absorbtion of solar rays on the other side, we could achieve, if not 27°C, at least 20° or 15°C, which is quite adequate. We could use heating, but this is unnecessary, considering the constant,

if weak, radiation of the Sun. In fact, we could increase the temperature of the rocket at will, by beaming solar rays on it with a system of mirrors. There, in ether, metal mirrors would become neither dim nor deformed under gravity, since it is nonexistent outside or inside the rocket."

"Well," a young worker remarked, "it's clear that the rocket need not fear the cold. What I can't understand, though, is why the relative gravity in the rocket, when fuel combustion begins, doesn't crush the passengers. You said that it could increase tenfold for a short time, which means that if I weigh 80 kilograms now I'd weigh 800 in the rocket. If my head weighs three kilograms, it would weigh thirty in the rocket. Why, it would be just as if you had loaded over 700 kilograms on me! I couldn't stand it! My blood would be almost as heavy as mercury! My blood vessels would burst and my hands would be torn off by their own weight."

"That's so!" a chorus of voices exclaimed.

"True enough," Galileo confirmed. "And yet our friends will remain hale and hearty, because they are submerged in the recumbent position in a liquid of the same density as the mean density of their bodies. You'll understand when I show you an experiment. Observe this figurine, which is made of a very fragile material. I drop it and it breaks into pieces. Now I take a similar figurine and place it in a strong transparent sphere filled with a liquid of the same density as the figurine. Observe that it neither buoys up nor sinks down, no matter how I turn the sphere. Now let us throw the sphere and hit it with a hammer. You see the figurine is intact. Now I place the sphere in a centrifugal machine and by rotating it increase the weight of the figurine, the sphere and the liquid a hundredfold. See, the figurine still remains intact."

"The reason is," Helmholtz interjected, "that the weight of the liquid balances the weight of the figurine, so that its members don't press against each other or the walls of the sphere. It doesn't even touch the walls."

"Different parts of the human body," Galileo went on, "have different densities. Bones, muscles and fats are all of different density. This makes for some tension between them, which increases considerably when the relative gravity is great. But a tenfold increase is not enough to cause a rupture of the tissues. We can perform the same experiment with living creatures: a fish, a frog, and so on. We can increase their weight a hundredfold. See, they all remain alive."

"Gentlemen!" someone exclaimed. "These creatures are alive, but how about our friends travelling beyond the atmosphere? Are they well, and where are they?"

"They may be flying over our castle at this very moment."

All eyes turned involuntarily to the transparent dome.

"What is that little star creeping eastward?" a very young worker asked. "Could it be an aerolite?"

"Where? Where?" several voices asked. "Oh, there it is! There, there, in the constellation of Cassiopeia!"

"Gentlemen," Galileo said, "that is no meteor. A meteor leaves a trail in the atmosphere and usually disappears rapidly. This star leaves no trail. Furthermore, it moves much more slowly and, as you see, remains in the sky.

"Ten hours have passed since our friends embarked on their flight. In this time they must have circled the Earth six times. What we probably see is the rocket displaying a powerful electric light. Our friends are signalling to us that all is well."

Galileo had hardly uttered these words when the star began to blink, disappearing and reappearing again at regular intervals.

"Unquestionably our friends are there," Helmholtz said, "and they're communicating with us by Morse. They are reporting that everything is well and they are alive and in good spirits."

The meeting broke up in a tumult of joyful cheers. Eyes sparkled and everyone breathed more freely.

15. INSIDE THE EARTH-CIRCLING ROCKET. THE COMBUSTION ENDS. EMERGING FROM THE TANKS. CONVERSATION

Let us see how our friends are faring in the rocket. We know that they felt well in their water-filled "coffins". They communicated with each other and freely moved their limbs. Their only concern was not to expose a single limb of their bodies, otherwise it would become very heavy and fall back into the water like a piece of lead. Their bodies could be exposed only after the rate of combustion was reduced. Ten minutes later the oppressive roar of the rocket ceased and only a ringing sound lingered in their ears.

"The motors have been switched off," Ivanov informed the others, and proceeded to emerge from the water.

The sensation was as if the rocket had suddenly stopped moving. Yet they were hurtling forward at a terrific rate. The only thing that had ceased was the chemical reaction between the combining propellants. Many were reluctant to leave the water, just as we are often reluctant to get out of a soft bed in the morning. They saw the Russian clamber out of his tank and several times fly back and forth about his compartment before he finally grasped something to cling to. The water creeped out of the tank and flew about in drops until they hit the walls and the water spread all over them. Ivanov laughed as he dried himself with a towel.

"Gentlemen," he said, "it's time to get up, you've rested long enough."

Urged on by curiosity, our companions quickly clambered out of their tanks, and found themselves repeating Ivanov's antics. They still felt a ringing in their ears, but their laughter and vociferations drowned that nervous sound. They dried themselves and donned light clothing. The water was carefully collected and deposited in the tanks. Everything was set in order. Loose objects drifting

back and forth, tumbling until they gradually slowed down, were all firmly secured in their places.

The crew gathered in the big cylindrical cabin in the middle of the ship. It was about four metres in diameter, like the other compartments, but five times longer, i.e., 20 metres. It was large enough for 20 persons. The doors leading to the other compartments were open, and our companions flew in one after another: one sailing sideways, another upside down, though each thought it was he who was right side up, and the others were not, that he was motionless while the others were flying about. It was difficult to keep from moving. The sensation was very weird and called forth no end of witty remarks, jokes and laughter. The men's eyes bulged from fright, perhaps, or surprise. . . .

"Gentlemen, we'll be having much more occasion for surprise and merriment," Newton remarked. "Let us calm down and discuss our situation. I mean not your sensations but our position in outer space."

The hubbub subsided, but the men continued to drift about and jostle each other like fish in water, only their bodies pointed in different directions. Everyone was all attention.

"Judging by the time," said Laplace, looking at his watch, "we've left the atmosphere behind. The rocket seems to be at rest, but that is purely illusory. According to the previously drawn-up programme carried out by the automatic pilot, the rocket should now circumnavigate the Earth forever. Its location is very stable: one thousand kilometres from the Earth's surface, travelling in a circular orbit with a constant speed of about $7\frac{1}{2}$ kilometres a second, and circling the globe once every hour and forty minutes, approximately. Like the Moon we are now an Earth satellite and like the Moon we can never fall back, because the centrifugal force is balanced by the attraction of the Earth.

16. SUBJECTIVE SENSATIONS

"Gentlemen, we're not moving at all!" an anxious voice exclaimed. "We're sealed off in an illumined vault going nowhere. I can't understand what's happening and I don't believe we're moving or anything. . . ."

"I must be going mad," someone else said. "Everything is in commotion, nothing keeps its place, and we've just become so many birds or fish. But they, at least, can keep their balance, while we twirl about head over heels and bump into each other, even though the room is large enough. I know I've lost my relative weight, but I never expected to feel as I do now. It's positive phantasmagoria! My heart jumps every minute and I'm afraid of falling as soon as I see that nothing supports me. . . ."

"Be calm, friends," the Russian said. "We'll gradually become accustomed to this strange state and it will seem quite natural. As to your doubts, they'll be dispelled as soon as we open the shutters and see God's world. I think, however, that we shouldn't hurry with this: we're wrought up as it is, and there's no telling what will happen when we see sky and Earth changed beyond recognition. Some of you may wonder at all these precautions, but the view may be so startling that the first impressions may completely unnerve you. At the same time, however, I can reassure you with the news that Laplace has already looked out of a small porthole and found that the rocket has become a satellite of the Earth, we are in complete safety, and everything is proceeding according to the programme.

17. PURSUITS, SLEEPING, READING, EATING

"Instead of getting worried," said Franklin, "let us rather think of our 'home' and engage in something more pleasant. It's light, warm and clean here, the air is pure, there are twenty of us. . . . We can read, sleep, eat, converse or retire to our cabins, of which there are twenty

besides this fine drawing-room. Let one remain on duty to look after the temperature and air-conditioning."

"Hear, hear!" several voices exclaimed. "Let's retire to rest or converse," and the rocket's inhabitants fluttered away in ones and twos and threes to their respective cabins. The cabins were lit up and had all the necessary conveniences. To move around the men had to push against the walls. This mode of travel was not so easy, and many collided with door jambs, from which they rebounded to continue their flight. Others, however, were nimbler and shot through all the doors without brushing against a single one. When one of them reached his cabin, he had to steady himself at the wall before diving in. Some put out the electric lights and went to sleep in mid-air, the slightest involuntary motion sending them drifting slowly from one end of the room to the other. Even breathing and the circulation of the blood affected their motion and position. There were no beds, but no one complained of hardness. It was warm, too, and when preparing for sleep, each member of the crew could raise the temperature of the air in his cabin by several degrees. If he preferred to keep his head cool he could crawl up to the neck into a special woollen sleeping-bag. Some took books to read. There were light folding frames to which one could strap oneself to avoid floating about. This was convenient for reading at a lamp, but for sleeping it was not necessary. Those who customarily tossed about in their sleep could fasten themselves to two straps attached to the walls or slip behind a net screen, rather like a fisherman's net. A book could be held with the greatest ease since it weighed nothing, but the pages fanned out and had to be clamped down by a spring or simply held down with a finger. Some found solace in talking about the Earth and in nostalgic reminiscences of the life left behind. Others refreshed themselves with food. Special provisions had to be taken for eating and drinking in the rocket, as the normal procedure was impossible. A table and chair would not stand

in place and the slightest push would send them drifting away in all directions; you could catch your furniture and set it down, but it would only float off again. The furniture, of course, could be screwed to the walls, but what need was there for a table, if the dishes didn't fall? What need for chairs or couches if a person could rest on air and wouldn't move unless pushed? What need for beds, spring mattresses, blankets and pillows if the air was softer still? Merely to create an illusion of the terrestrial way of life? But what was the use of an easy chair or bed, if you could stay in it only if you were strapped down! Plates and decanters and the food itself would have to be fastened. If you laid your spoon or fork on the table and it sailed away towards your neighbour who had to be on the alert to prevent a fork poking his eye out or a knife from grazing his nose! It would swing on a string or describe circles, smearing the table or the face of your neighbour. When cut loose, crumbly food would scatter about and get into your nose, mouth, eyes, ears, hair and pockets. They would sneeze and cough and rub crumbs out of their eyes and fat off their faces. If you wanted a glass of water, the water would not pour. You could throw back your head to toss off a glass of wine, but the wine would fly out, break into several large globules and float away, wetting the hair and clothes of diners or entering the mouth of someone who had had no intention of drinking....

For chairs there can be light racks to keep a person in place; for tables, similar racks, for food containers—something like a light what not with many compartments from which the food and drink containers could be taken and then clamped back into place. All this was available in the rocket, for the scientists had foreseen and provided for practically every exigency. The food was in closed containers. Semi-liquid and liquid products had to be pushed out of their containers by pumping in air, which pressed on a special piston forcing the liquid through a valve with a flexible tube attached to it. The would-be

diner took the stem in his mouth and opened the valve for a moment. The semi-liquid food entered the mouth from where it could be pushed down into the oesophagus by the tongue and then swallowed. Solid food and such semi-solid dishes as jellies or fruit were kept in plates by springs and nets. A person pinned a piece down with his fork, cut off a morsel and dispatched it to his mouth where he could make short work of it with his tongue and teeth. Knives, forks and other implements had to be strapped to the already secured plate or its support.

18. PHYSICAL AND CHEMICAL EXPERIMENTS. A CONCERT

When they had rested, the scientists invited the crew to assemble in the drawing-room to see some physical and chemical experiments connected with the absence of gravity.

"As you will have observed from the very fact of our conversing here," Newton began, "sound propagates here just as it does in the Earth's atmosphere. The gas inside the rocket has retained its elasticity, and consequently its ability to vibrate. . . ."

"Let's sing a song to illustrate this," someone suggested.

"Fine," said Laplace, "and we can add music."

The assembly agreed. Musicians unfastened themselves from their racks and flew away to fetch their fiddles, trumpets and scores. They were back in no time. Most of the company preferred to strap themselves to the racks described before to keep from tottering or drifting away in all directions. Otherwise the assembly looked quite respectable. The conductor gave a sign and the chorus began singing to the accompaniment of musical instruments. They sang with such gusto that one might have thought they had been long deprived of music. Many forgot they were not on the Earth and, hovering in mid-air, muttered

remarks quite out of keeping with their existing state. The final chord rang out, everyone applauded and cried "encore". They sang several more songs with equal success, until finally the musicians pleaded for mercy.

"You thus see," said Newton, "that we have no lack of sound. Any experiment in acoustics staged here would be an exact replica of a similar one on the Earth.

"There is no gravity, that terrestrial measure of mass," he went on after a pause. "And yet we can feel mass here, especially when we wish to impart motion to bodies. The greater the resistance of a body to your push, the greater its mass. The mass of any body is immediately registered by the hand pushing it.

"But of course, neither a spring balance nor scales can register mass here: the spring doesn't stretch, the balance pans remain in equilibrium in any position regardless of the load. Still, mass can be determined with great accuracy with the help of various instruments, notably a suitably devised centrifugal machine. Mass is also manifested when we stop a moving body with our hand. The harder it is to stop one of several bodies moving with the same speed, the greater its mass. Mass is further manifested in impact, being proportional to the impact force. The speed of a mass should also be taken into account, for a small mass travelling at a high speed may produce a strong blow, and vice versa. Firearms are more effective here than on the Earth."

"Disregarding the resistance of the air," Ivanov noted, "motion here is rectilinear, infinite and uniform. The influence of the Earth and other bodies can also be felt; but in the rocket and within a radius of several tens of kilometres it is negligible."

"Here is a mercury barometer," said Franklin. "You see that the mercury fills the whole tube. No matter how long the tube, the mercury will fill it to the top, because it has no weight. But the aneroid barometer or the manometer do their work here, because in them the gases press

on a tube or membrane, the elasticity of which is manifested even without gravity."

"An ordinary pendulum doesn't swing here and a pendulum clock won't work. If we push a pendulum it will merely revolve about its point of suspension until halted by the resistance of the air. But a watch and other machines and instruments the action of which is not based on gravity, operate well,—a sewing machine, for instance.

"Heated air doesn't ascend because there is no 'above' here. A burning candle or paraffin lamp goes out because there are no convection currents and the flame is enveloped in the combustion products through which oxygen penetrates very slowly by diffusion. On Earth many apparatuses are based on combustion in the oxygen of the air. Here furnaces and similar installations will rapidly break down without a stimulated blast.

"Hydrogen and other light gases don't rise here and they can't lift balloons, for there is no direction in which to lift them. Aeroplanes are unnecessary, and all that is needed is a motor for translatory motion. A heavy body hovers without support side by side with a light one, and neither moves unless pushed. The same is true of liquids, in which bodies of any weight, shape and volume remain in equilibrium. Archimedes' law for bodies submerged in water is useless here because, being based on gravity, it is just non-existent.

"Liquids cannot be siphoned, but air and suction water pumps work, of course, if there is a surrounding elastic medium, as there is in the rocket. Power water pumps and centrifugal pumps even work in a vacuum.

"Fountains, which are based on gravity, are here impossible, but those based on the elasticity of the air work wonderfully, producing a straight smooth jet, like a glass rod. At some distance, however, this jet bursts into a volley of flying water bombs.

"Liquids, of course, can't flow out of vessels, they aren't

bound by horizontal surfaces and are not distributed according to density.

"Molecular forces in bodies are especially manifest in liquids. As a result, every liquid mass, no matter how great, takes the shape of a sphere. You can break it up into several masses, and each will gather into a globule. Water enters a tube of any size of its own accord and fills it completely. The molecular forces of non-wetting liquids, on the other hand, force them out, like mercury from a glass tube. Nets, frames, vessels and other solid bodies can give liquids any desired shape. Thus, we can produce various double-convex or double-concave lenses out of water or oil and use them in optical instruments. We can even build complex telescopes, and microscopes with wire frames and liquids.

"Fire engines of all types can work only if provided with forced-draft fire-boxes. But water in a boiler won't separate from the steam, which may cause a breakdown in conventional engines."

"Maybe we've had enough physics?" an old worker ventured, when the Englishman paused for breath.

"All right," Newton agreed. "Let's postpone our talk and experiments for another time."

"Gentlemen," a young worker objected, "why not just have a break. We can have tea or coffee, relax and then continue. I'd like to know how our rocket's exhaust nozzles work."

"Fine, agreed," a chorus of voices concurred.

They arranged their racks round a large vessel in a frame attached to the rocket with twenty pipes issuing from it. The water was heated by electricity in a few minutes, tea and sugar were added and the beverage was left to cool a little. Some air was pumped into the vessel, each man took a pipe stem into his mouth and drank the excellent tea by opening a tap.

Refreshed, they cleared away the tea things and prepared to listen.

"You raised the question of the rocket," said Newton, turning to the young worker. "I was just preparing to discuss the question. Segner's wheel, the water-mill and the water turbine cannot work here, as there is no gravity. But we can demonstrate other reaction instruments, which are operated by springs, steam, the elasticity of gases or other forces not dependent on gravity.

"This little boat carries a hidden spring which shoots out beads. Observe how well the boat moves in the opposite direction. Take this box. The force of compressed air in it throws out a jet of water. See how it travels with increasing speed across the room. Here is another vessel, an airship, if you like. A jet of steam ejected from the tail end propels it marvellously. See how strongly it hits the wall."

"Steam can be replaced by an explosive, as in a toy rocket," Laplace remarked.

"Of course," Newton agreed.

"That's all very well," the young worker said, "but all these devices work so well here, in a gaseous medium. The ejected bodies are repulsed, pushed away by it. If it weren't for this atmosphere there would be no motion."

"The motion of our own rocket contradicts your conclusion," Newton observed. "Our vehicle has travelled hundreds of miles through vacuum with mounting speed propelled by the pressure of the elastic products of combustion."

"We can make the devices displayed here move in vacuum," Ivanov declared.

A tiny little vessel with compressed air was again launched before the audience. Tied to a rod passing through the plate of an air pump, it described circle after circle like a fettered horse. Then it was covered with a large bell and the air was rapidly evacuated.

"Gentlemen! Observe that the motion, far from stopping in the rarefied atmosphere of the bell, is accelerating. Hardly any air remains under the bell, yet the ship contin-

ues to move until it exhausts its store of compressed air. The answer to the question posed is thus self-evident."

"The main thing in this, my friends," Newton went on to explain, "is the inertia inherent in all gases, just as it is in all other states of matter."

"What, then, is the basic principle of reaction engines?" one of the group asked.

"It is simple," Newton said. "Imagine two balls with a spring compressed between them in a gravity-free field. If we let the spring go, it will push one ball to the right and the other to the left. The same will happen if two rubber balls are pressed tightly together and then released, in which case there is no need for a spring. Or imagine a tube with compressed gas. If one end is opened, the gas will press only on the other end, causing the tube to move, say, to the right, the gas escaping to the left. This is very much like the action of our rocket. The same happens when a shotgun or cannon is fired."

"It seems, then," a young engine operator remarked, "that in all these experiments the material medium, or atmosphere, surrounding these contrivances plays a secondary part and may even reduce the total reaction force."

"Quite right," Ivanov confirmed, "though the role of the atmosphere is not yet quite clear."

19. OPENING THE SHUTTERS

After dinner and a brief rest everyone gathered again in the drawing-room.

"Friends," said Newton, "we shall now open the shutters and see a wonderful sight. Those who don't trust their nerves had better not take part in this ceremony."

"Ceremony, indeed!" muttered one of the men suspended in mid-air.

"The more courageous will then tell the others what they've seen, and so prepare them for some unusual impressions," Newton went on, ignoring the remark. "Our

supplies of light, different forms of energy and food are very small. We'll have to begin by limiting our consumption of electricity and making use of the daylight. . . ."

One of the double shutters was opened and the lights were turned off. A dazzling beam of sunlight pierced the hall. The other shutters were opened and the more daring members of the crew flew over to the portholes.

The sight was hailed with cries of delight:

"The sky's pitch-black!"

"It's blacker than soot!"

"What a vast number of stars!"

"And they're all sorts of colours!"

"The constellations are the same, but there are more stars! But why are they so lifeless? They don't radiate or twinkle and they look like mere dots. How clearly they stand out! They seem so close and the celestial sphere so small!"

Men at other portholes saw the Earth at a distance of a thousand kilometres. They didn't realise at first that they were looking at the terrestrial globe. But then they began to recognise the familiar contours of lakes and islands and continents amidst patches of clouds. It was like a huge, distorted map of a hemisphere. In actual hemisphere maps, the edges are clear and their scale is double that of the central portion. Here the reverse was true: the edges were reduced radially and very vague.

"How strange our Earth looks! It occupies almost half the sky (120°) and seems to be not convex but concave, like a plate with people living on the inside."

"The edges are uneven and in some places they're jagged because of the mountain peaks. Something like a mist lies farther in from the edges and there are many elongated grey spots—clouds darkened by the thick layer of the atmosphere. The spots stretch round the Earth's circumference. The farther they are from the edges the lighter and broader they seem, and towards the centre they're rounded or irregular in shape, not stretched out."

"The Earth, Sun and stars seem very close, practically within reach! They all seem to be attached to the inside of a very small sphere."

"The Sun seems small, close and bluish, but how hot it is! The stars, too, are mostly bluish, but some are of other colours as well."

The men were stunned by the sight, some felt exhausted and moved away from the portholes. Others, alarmed by their cries, hesitated to look out. Many flew away to their cabins, drew the shutters and lit dim electric lights. Others, however, darted excitedly from porthole to porthole with cries of surprise and delight. They were like children on their first train or steamboat journey. The Earth fascinated them most. It was full at first, but waned as the rocket sped rapidly eastwards. Gradually it turned into a huge crescent moon. Its dark side glimmered in the weak light cast by the Moon. The boundary between the dark and daylit parts (the terminator) appeared rough and broken due to shadows cast by the mountains. The Moon could also be seen in the sky. Like the Sun, it seemed very close and small, much smaller than usual. Actually, though, the angular dimensions of the Moon, Sun and stars had hardly changed at all.

"Gentlemen," Newton said, "our rocket is circling the Earth once every 100 minutes. The solar day lasts 67 minutes, and the night, 33 minutes. In 40 or 50 minutes we shall enter the Earth's shadow. The Sun will set almost instantaneously. We'll hardly see the moonlit Earth, but its edges will shine brightly with all the colours of the dawn. This light will be our substitute for moonlight.

"I'm warning you in advance what to expect to prepare the people whose nerves are not strong. . . ."

Meanwhile the Earth continued to wane and at the terminator the oblique shadows of mountains and elevations grew longer and longer. The impression was as if the stars were falling to the jagged sunlit edges of the Earth in tens, hundreds and thousands, so large was the portion of

the sky occupied by the Earth and so great was the number of stars that could be seen in the void. At the other edge, where its dark side looked vaguely, with huge serrated shadows cast by the descending Sun, the stars seemed to appear out of nowhere. Actually they were emerging from behind the dark face of the Earth which had eclipsed them. The rate of motion of the stars was 3.6° per minute, which meant that they travelled the diameter of the Sun or Moon in eight or nine seconds. That, approximately, is the apparent motion of all celestial bodies—the Sun, Moon, planets and stars—in relation to the Earth. The size of the seas and continents, as seen from the rocket, can be imagined from the following comparison. In optimum conditions, a distance of 100 kilometres, or one equatorial degree, could be observed at an angle of 6°, i.e., 12 times wider across than the Moon. Features not too far from the central portion, which was not so much obscured by air and clouds, could be seen in considerable detail. The sight was an impressive one. They could see cities, large villages, rivers more than a hundred metres wide. Sometimes the land below assumed one colour, as if covered with snow, and it was difficult to see anything. The view presented by a telescope can hardly be described. The rocket had no atmosphere to distort the image or obscure the smaller stars. The sky was so tightly packed with stars that there was hardly an empty space left: a black sky powdered with silver stardust, with the exception of the so-called coal-sacks, which were as black and empty as viewed from the Earth.

Binary, ternary, multiple, and vari-coloured stars could be seen everywhere. The moment of eclipse, or night, was approaching.

"Gentlemen!" someone exclaimed, "the invisible edge of the Earth has covered one side of the Sun."

In four seconds only half the Sun remained, and four seconds later it was night time. Their eyes soon grew accustomed to the darkness, however, and they could see

a glowing ring of dawn circling the dark Earth. The dawn was especially bright where the Sun had just disappeared. The beautiful halo was about 10 degrees high. It gradually became uniform in size, and 16 seconds after sunset it presented a continuous colourful ring embracing almost half the sky (its diameter was 125°). The crimson glow was bright that one could read without artificial light. Some found the sight unbearable. Others continued to dart from porthole to porthole with cries of delight. As it was comparatively dark many more stars could be seen on the opposite half of the sky. They continued to fall like snow into that flowing sea, only to burst forth from the other side of the crimson ring like sparks from fireworks. Gradually the ring paled on one side and brightened on the other, passing through different hues. Scarcely 17 minutes had passed when a strip of the Sun appeared. Everything sparkled and the glow of dawn dimmed. In nine seconds the full Sun emerged in all its glory, blinding everyone with its light.

"Not much of a night," a young worker remarked. "Only half an hour!"

"It was an eclipse, not night," a friend corrected him.

"It was both night and eclipse," said Ivanov. "This is the only night we'll have and other nights will be as short. An hour-long day (67 minutes) is followed by a half-hour night (33 minutes). Unless we change the speed of our vehicle we'll have to put up with this rapid succession of short days and nights."

"Did you notice the coolness of night?" Newton asked.

"No, we didn't feel cold," several voices replied.

"That," Newton explained, "is first of all, because our rocket is protected by a layer which keeps it from radiating heat, secondly, the night was very short, and finally, the huge, though dark, surface of the Earth radiates heat towards us. Generally in the course of our brief night the temperature should fall one degree centigrade or even less."

"Thus, the short day and proximity of the Earth have

their advantages," Franklin remarked. "Namely, we have no cold nights."

"We needn't mind our nights. After all, we can't sleep for half an hour! We aren't accustomed to it. I suggest that we stay up for 16 hours and sleep eight hours, approximately, of course. Everyone can arrange his own night by closing the shutters or make day with the aid of electricity. In short, we can keep sleeping and waking hours at will. No danger threatens us and we have no need to keep watch or arrange shifts."

Several days and nights passed, but actually it was only 10 hours. In one of these short nights they passed over the Himalayan Mountains. They could see the familiar snow-capped peaks, but they couldn't discern the castle even through a telescope. Laplace suggested that they telegraph to their friends in the castle by means of light signals in Morse key. It was simple, and all that was required was to press a button which sent a powerful current to an arc lamp of 100,000 candle-power. It was the light of that lamp that had been observed and understood at the castle. A long push of the button gave a long light, which was received on Earth as a dash, a short tap produced an instantaneous flash which was received as a dot.

* * *

It was decided to have a good terrestrial sleep. Refreshed after sleep and a cup of coffee, our friends assembled in the drawing-room.

"I request your undivided attention, gentlemen," Newton addressed the meeting.

The conversation subsided.

"So far we have only observed, admired, wondered at, and studied the conditions of our new existence. We examined and inquired, but we gave no thought to our daily bread. Our vital stores are not too plentiful. Before we have exhausted them we must decide whether we shall remain here until they are exhausted and then return to

the Earth—which we could do a hundred times with our stock of propellants—or try to produce the necessary things for life here before we use up all our supplies. Then we can remain in the ether for a long time."

"Let's remain in the rocket and try and grow our bread," one of the company suggested. "If we are unable to provide for ourselves we can return to the Earth."

"Hear, hear!" several voices cried. "Why not try?"

"But shall we be able to produce oxygen and food?" a sceptical voice asked.

"If we fail, we'll return home," a young mechanic said.

"Well, the risk is not great."

"It's decided, then, that we remain up here!"

20. PROTESTS. LONGING FOR WORK. ARTIFICIAL GRAVITY

But there were dissenters as well.

"Better return!"

"I feel somewhat peculiar."

"Something's missing," they complained.

"I feel an itch in my muscles. They need some work, I think."

"That's easily remedied," Ivanov remarked. "We've got several kinds of treadle tools—get down to work!"

"That's easier said than done," a worker observed. "As soon as I press my foot on the pedal I'll shoot upwards: there's no gravity!"

"That's so," said Laplace, "but if you looked closer you'd have noticed certain attachments to all the tools: straps in the floor for your feet and a waist strap which, however, leaves you with complete freedom of motion."

Thus our dissenters were given work for the common good and were thereby made completely satisfied.

* * *

There were dissenters of another category, however, who longed for gravity.

"I want to see water pouring and weights falling," one of them said. "I want to sit and recline properly."

"There's no need to return home for that, either," Newton said. "Nothing could be simpler than simulating gravity here. For this we merely have to revolve our rocket—best of all about its middle lateral axis. Centrifugal force will generate gravity in every cabin. The gravity will be greatest in the outermost compartments and least in the middle one, i.e., in the drawing-room. Objects will fall along the rocket's longitudinal axis, water will pour, and everything will be as on the Earth: you can sit, recline and walk, get tired, carry weights and pails of water, etc."

"For example," said Laplace continuing Newton's thought, "if one end of our rocket, which is a hundred metres long, sweeps through one metre a second, the synthetised gravity will be 0.002 of terrestrial gravity, or the same as on a planetoid 24 kilometres in diameter. The rocket will describe a complete circle in 314 seconds (5 minutes). If the speed is increased to 10 metres per second, the gravity will increase a hundredfold and be 1/5th of terrestrial gravitation, which is slightly more than on the Moon. The rocket will describe a complete circle in half a minute. This is still slow enough not to cause dizziness."

"There are several ways of making the rocket rotate," Newton said. "For instance, if we spin this wheel, or just give it an initial push (it will continue to revolve by inertia) the rocket will start turning. However, rotation is easier achieved with the help of the two exhaust nozzles by turning them in opposite directions perpendicular to the rocket's longitudinal axis."

This was done and the dissatisfied were appeased. Having worked themselves to a sweat and revelled in gravity, they pleaded for relief. The rocket's rotation was stopped by directing the exhaust opposite to the rotation. Only a negligible part of the powerful propellant discovered by Franklin was used for this manoeuvre.

"Well, gentlemen," Newton said, addressing the crew, "we've humoured ourselves sufficiently and it's now high time we got down to work while our supplies are still plentiful."

"You will have noticed," he continued, "the great number of portholes along one side of the rocket. If all the shutters are opened, the total windowed area will be eighty by four metres (one-third of the circumference of the rocket). Up till now we've had no use for such an abundance of sunlight, which would be unbearable: it would get too hot and the bright light would weary the eyes. This volume of light falling on an area of 320 square metres, or 16 square metres per person, can yield, with the aid of certain plants, considerable quantities of oxygen and food in the form of fruit containing starch, sugar, oil, nitrogenous and aromatic compounds."

"Even if we are unable to maintain our food supplies at one level," Ivanov added, "we can at least consume them much more slowly."

* * *

The excretory products of the lungs, skin, kidneys and other organs were absorbed in special vessels and provided excellent nourishment for the plants. Seeds were planted in boxes with soil fertilised by these excretions. When the seeds sprouted the boxes were placed in the light and the shutters were opened wider and wider. The unusual force of the sunlight, not weakened by the thick layer of the Earth's atmosphere, its continuous action, the vertically-falling rays, the absence of pests, and favourable water and air supplies all combined to work miracles: hardly a month had passed when the diminutive plants were covered with juicy, nutritious, fragrant fruit. The blossoms were a wonderful sight. Fertilisation was artificial. Thanks to the absence of gravity the plants branched

freely in all directions and the fruit did not weigh them down. When the foliage became so thick as to almost obscure the portholes the glass shields were removed, leaving only the quartz. As a result, the plants abundantly provided with ultra-violet radiation, developed twice as fast. Still, the yield was not sufficient to satisfy the food problem; besides, the oxygen supplies had to be used for breathing. Nevertheless, things were going so well that it was decided to build, at a later date, a greenhouse outside the rocket in order completely to meet all food requirements and, as it were, to enable them to stand on their own feet.

22. DONNING SPACE-SUITS

While the seeds were sprouting, growing, blossoming, ripening and yielding fruit, our companions were not marking time. They decided to investigate the space surrounding them and leave their rocket, their wonderful blooming, fragrant haven, and take a broader look at God's world than was possible through the portholes.

We shall describe this event. One day the boldest member of the crew remarked, as he admired the beautiful flowers:

"It's very nice in here. The air is clean and we've got plenty of space: a hundred-metre corridor along which we can fly back and forth to our heart's content. A hall 20 metres long with ceilings four to five metres high provides lots of elbow-room and space to fly about and gambol in. We have light and merriment, food and warmth. We're in high spirits. If anything goes wrong we can return to our beautiful Earth: there it is, a mere thousand kilometres away!

"This is all very well," he went on, "but shall we never leave these walls and go out into the boundless, though seemingly limited, space that we see through our portholes?"

"Why not? It is quite possible," Newton said. "We have all the necessary contraptions to do it. They were prepared back on the Earth: special suits, provided with breathing apparatus and absorbing the waste products of the body."

"Well, why not open a porthole or door and fly straight out?" someone asked naively.

"The Sun is shining so brightly, it looks so delightful, it would be fine to get out of doors!"

"Firstly," Laplace interposed, "we can't open a door or a porthole: the air would immediately rush out of the rocket and we'd perish at once, for our bodies require atmospheric pressure and oxygen. Secondly, even if that were not to happen, the direct rays of the Sun would kill any mortal who failed to shield himself with suitable transparent or opaque covers."

"But why is no one killed by the Sun on Earth?" someone asked.

"On Earth the strength of solar radiation is halved by the thick atmosphere," Franklin observed. "What is more important, it is rendered harmless, though not completely, for sun-stroke is not infrequent, especially in hot countries and high in the mountains where the atmosphere is rarer and more transparent."

"Finally," said Newton, "even if we left the rocket without letting the gas out—which is easily achieved—we wouldn't find a single molecule of gas for at least 800 kilometres (to where the Earth's atmosphere begins). How can we breathe and get along without the customary, essential pressure on our bodies? I ask this question only to demonstrate to you that we can't simply leave the rocket through an open door."

"But what are we to do?" the one who longed for space asked.

"All these problems were solved by us on Earth," Newton said. "Ivanov, please bring the suits for survival in vacuum. You know where they are?"

"Certainly. I'll be back in no time."

He returned in a few minutes with two space-suits.

"I'll explain how they work," Ivanov said, demonstrating the suits and equipment. The others gathered closer round and looked on with interest.

"Some day," Ivanov began, "we may have to land on planets into atmospheres unsuitable for breathing either because of their composition or their extreme rarefaction. The same type of outfit is suitable for survival in a void and in rarefied or hostile atmospheres. Here you see a suitable space-suit. It covers the whole body including the head, and is gas- and vapour-tight, flexible, light, and allows the body freedom of movement. It is strong enough to withstand the internal pressure of gases surrounding the body and the helmet has special flat visors. It has a thin, warm living through which gas and vapour can pass. It has reservoirs for urine and other purposes and is connected with a special cylinder which provides an adequate supply of oxygen. Carbon dioxide, water vapours and other products excreted by the body are absorbed in special vessels. Automatic pumps continuously circulate the gases and vapours inside the suit through the permeable lining. Each man needs not more than a kilogram of oxygen a day. The suit has an eight-hour supply, and its total weight is 10 kilograms. Here, however, it weighs nothing. The suit, you will observe, doesn't even disfigure the wearer."

"We'll need these suits in our future greenhouses where the gas will be very rarefied," Franklin observed.

"And also for building the greenhouses," Newton added.

"And now, gentlemen, which of you would like to don this suit and have a jaunt in space?" Laplace asked.

All but two young workers retreated hastily as if they had been scolded. The two were helped into the space-suits. Capering comically, they several times pranced about the room to the delight of the others. Their voices were quite audible through the suits.

"Well, gentlemen, are you ready?" Newton inquired. "Oh, one moment," he added, "if you go as you are, you'll be uncomfortably warm. Bring them a couple of light white cloaks. Here, fling them on and attach them so that they won't fall off. If you feel cold," he instructed the two, "fling the cloaks aside until you get warm. Without the cloaks the mean temperature of the black space-suits may reach 27°C."

"The temperature can rise even higher," Laplace added. "if you use the white cloak to reduce radiation from the shaded part of the body and open the sunlit part completely."

"Yes, but above 20°C the heat is oppressive," Newton remarked. "So they'll more likely want to reduce the temperature than to increase it. For this they should use their cloaks to shield part of their bodies from the Sun."

"You realise, of course," the Russian said, addressing the spacemen, "that when you leave the rocket you'll fly in the direction you push off. You'll have no means of stopping of your own accord, and several years may pass before you meet the rocket again. Long before that you'll have starved to death or suffocated from lack of oxygen."

"What!" the two spacemen exclaimed. "Suffocate after eight hours? That's more than we bargained for. Wander about in space to die? You should have warned us!"

"I'm not going!" one of them declared flatly.

"Neither am I," the other echoed from his space-suit.

"Undress me, immediately!"

"And me, too."

"What cowards you are!" Newton said. "I haven't finished yet. You'll be quite safe. First, we'll let you out on a leash. . . ."

"Like a dog? Gratified, I'm sure."

"It'll be a kilometre long and you'll be able to fly in any direction and be sure of returning."

"What if the leash snaps?" the elder of the two asked, fearfully.

"You've nothing to fear. You will be provided with a special device which acts like a rocket and which you can steer, by regulating the gas jet. With its help you can fly in any direction and return home whenever you want to."

"The main thing is not to lose sight of us," Franklin admonished them. "Otherwise you may lose us completely. Each of you take a spyglass for safety's sake. Here, I'll fasten them to your cloaks."

"But what if I use up all the propellant?" one of the spacemen inquired. "How will I be able to return to the rocket even if I'm a couple of feet away?"

"You have an adequate supply of propellant, but you should expend it with care. Don't use it all up: this indicator will tell you how much of it you have left. Besides, if you get lost we'll find you and bring you back home."

"What if you don't find us?"

"Anything may happen," Ivanov said.

"Then we'll be done for!" the spaceman said, with a wry smile, which remained unobserved beneath his helmet. Pride, however, triumphed. It would be humiliating to get out of the space-suits in front of everybody and to be the laughing-stock of the crew.

"Come on! It's nothing," one of them encouraged the other. His resolve inspired several other volunteers.

"I wouldn't mind going myself," remarked one of the spectators, who was flying back and forth impatiently.

"Nor I!"

"Nor I!"

"Very well, but not now," Laplace said. "Let's dispatch those who're ready."

They were provided with everything necessary and one of them entered an air-lock, a very narrow box-like chamber. This was done by first opening the inner wall of the air-lock and then hermetically sealing it up. The remaining insignificant amount of air was then pumped out, so that

not a drop of it would be wasted. The spaceman no doubt looked bewildered but waited impatiently in the darkness. A minute or two later the outer door of the air-lock opened and he bounded out of the rocket. Soon he was joined by his companion.

The men inside gathered round the portholes. They could see the spacemen flying off in different directions, their leashes unwinding. They turned, veered, threw open their cloaks or drew them about their bodies, soared and whirled like toy spinning tops. Their antics, however, were familiar to our travellers, for they had experienced the same sort of thing inside the rocket. One of the spacemen unhooked his leash and flew so far away that they could hardly see him. He reappeared soon, growing in size as he approached the rocket, and sped close by. A thin cloud of smoke could be seen: the spaceman had switched on his jet motor and was steering himself towards the rocket. He grasped a bracket and peered in. The men inside could see his laughing face through the porthole. He signalled that he wanted to enter the rocket. He entered as he had left, the same precautions being observed, so as not to lose any air. The other man returned and was let in too. Everyone congratulated the two on their return and showered them with questions. There was quite a commotion. The men took off their space-suits and pleaded for rest and quiet.

"Have patience!" one of them said. "Let me digest my impressions, and then I'll tell you everything."

"Yes," the other rejoined, "give us a rest."

24. THE SPACEMEN'S STORY

Two hours passed, the Sun set and rose again before our travellers came to the drawing-room to describe their excursion outside the rocket. The others surrounded them, impatiently awaiting to hear their story.

"When the outside door opened and I found myself on

the threshold of space I faltered and made a convulsive movement which pushed me out of the rocket. I might have expected to have been already accustomed to hovering without support in this room, but when I glanced down and saw nothing below me, a complete void without support of any kind, I just fainted and came to only when the whole leash had unwound and I was a kilometre away. The rocket looked like a thin white rod at the other end of the leash. I was covered with the shiny cloak, which reflected almost all the sunlight. I felt cold, and that was probably what brought me out of the faint. I pulled on the leash and sped towards home. Soon I felt better, especially when I saw your inquisitive noses pressed against the rocket windows, I was ashamed of having shown my fear and of seeking refuge in the rocket. So after flying about on my leash I unhooked it and flew off on my own. When the rocket was almost out of sight I resorted to my jet motor and flew back. But it was frightening. You must have seen how I spun round, yet I myself felt nothing: it seemed to me that the celestial sphere with everything on it and even the rocket itself were all revolving about me. I was able to stabilise myself with the aid of the two levers operating special devices attached to my space-suit. These levers actuated two mutually perpendicular heavy disks. Thanks to them I was able to stop spinning and orientate my body at will or turn about any axis. As far as I was concerned, however, no one would have convinced me that I was not actually whirling the whole heavenly sphere round together with the Sun and stars, just like a merry-go-round. I could turn it quickly or slowly or stop it altogether. The axis of rotation of the sphere also depended on me. The rocket seemed to jump from right to left, and I was the only motionless object and could turn the Universe at will. At one moment I saw the Sun below me and it seemed that I would fall into its molten mass; my heart quaked, but I didn't fall. Then our Earth, which covered half the sky would appear below

me, and I felt that there was 'below' and I was 'above'. My heart sank again, and I felt as if I were falling and would dash my brains out or get drowned in the ocean. You could observe that I assumed the same postures as you do here, that is, I changed my position, if I got tired or for any other reason. If it felt cold and I forgot to draw aside the cloak to catch the rays of the Sun I huddled up as we usually do when the morning chill creeps into our bed. If it felt hot, I extended my limbs subconsciously in order to increase the radiating surface and give off the excess heat. If neither happened I changed my position whenever I felt like it: when I was tired of being prone I curled up, crouched, pulled up my knees, made swimming motions, shook my hands and feet and head, and moved my limbs if they felt cramped. When I was in translatory motion you could see me move, but as far as I was concerned, if the motion was strictly translatory I could swear that everything stood stock still, except the rocket which either approached or receded from me."

"Actually the rocket did move a little," Newton remarked. "But as its mass is 5,000 times greater than the mass of a man, its displacement was no greater than 20 centimetres."

"It seemed to me," spaceman continued, "that the rocket obeyed me dutifully whenever I pulled the leash. Only my rotation created the illusion of a moving sky.

"It's unfortunate that in these ethereal expanses, in this brilliant, beautiful and awesome world you are deprived of the satisfaction of motion. It may be that this subjective sensation will pass and then we'll feel ourselves move."

"There's hardly anything I can add," the other spaceman said. "My sensations were the same as just described, only I didn't faint. I felt frightened, but my fright passed almost at once. My nerves are stronger!

"Of course, gentlemen," he went on, "you all know how tremendous and free is the space surrounding the Earth,

how full of light and how empty it is. This is unfortunate. We are so cooped up on Earth and we prize every sunlit spot to cultivate plants, to build homes and live in peace and quiet. When I roved in the void about the rocket I was struck by its immensity, the freedom and lightness of motion, the mass of wasted solar energy. Who is to prevent people building greenhouses and castles here and living happily?"

25. REGULATING THE TEMPERATURE

"Pardon me for interrupting you," Newton intervened, "but you've reminded me of something of immediate importance to us. We'll deal with it at once. In what condition did you find the rocket's surface, which had been highly polished before?" he asked the spacemen.

"It was white," one of them replied. "I didn't pay attention to it."

"It had a dull silverish lustre and sparkled like snow," the other declared.

"This must have been caused by the high temperature to which the outer shell was heated during our flight through the atmosphere," Ivanov suggested.

"So far," said Newton, "we have maintained the temperature in our rocket by heating it a little and wasting our supplies of energy. Now we can discontinue this. We shall drape the rocket in a black cloak and so regulate the temperature. At night we can draw the cloak off. In the daytime, if it gets too hot, we can gather it into folds, just as you did with your own cloaks," he said, turning to the spacemen. "Now we can all leave the rocket and go about our affairs both inside and outside."

"We could paint a portion of the rocket," Laplace suggested. "That would be quicker, though it would be harder to regulate the temperature."

"As soon as we go outside," said Ivanov, "we'll take the necessary steps, and will no longer have to

waste our supplies of energy to maintain a constant temperature."

After a further conference it was decided to use easily removable paint to obtain the average desired temperature. The temperature of each small cabin could be regulated from inside by working a system of inside and outside shutters.

26. DISCUSSING THE SPACEMEN'S SENSATIONS

The company broke up for food and rest. They gathered again only eight hours later. The crew adhered to terrestrial time, which presented no difficulty in the presence of the Earth, Sun and Moon and with our scientists' thorough understanding of the laws governing the motion of celestial bodies and the rocket. An ordinary pocket watch served, and it was checked astronomically once in a while.

"You," said Newton, addressing one of the spacemen, "raised the question of the possibility of living in outer space and its advantages compared with life on the Earth. This is a very interesting question for discussion."

"There are many things I don't understand," one of the listeners interjected. "Maybe you would reply to several preliminary questions concerning the surrounding Universe?"

"You're welcome to ask your questions."

"Why, for instance, didn't the spacemen fall to Earth under the influence of its attraction once they left the rocket?"

"That is very simple. On leaving the rocket they had its speed, i.e., 7.5 kilometres a second. This is ten times the velocity of a cannon-ball and it is sufficient to develop a centrifugal force equal to the Earth's gravity. You can't fall down for the same reason that the Moon can't fall. Reduce the Moon's velocity, and in five days' time it will fall like a stone to the Earth and convert it into a ball of

molten, gaseous matter. As long as you move in ether the resistance of which, if it has any, has never been detected and, to say the least, is highly doubtful, you can't lose your speed. You travel like a bolide which, unless it enters the atmosphere or hits the Earth, will continue to coast along forever."

"That seems clear. Now, why is the sky black?" one of the hovering listeners asked.

"Did you ever climb a mountain?" Laplace asked. "If you did, you undoubtedly saw the sky grow darker and darker as you ascended higher and higher. At an altitude of ten kilometres an airman sees a very dark sky. The blue colour belongs to the air. Remove the air, and the colour disappears. Since there is no air here there is nothing to make the sky blue."

"What about the air in the rocket?" one of the men asked.

"Such a thin layer can have no perceptible colour, just as a thin layer of water or glass is transparent while a thick layer is opaque."

"That's clear, too. Now, why are there so many stars, why don't they twinkle, why are they so brilliant and differently coloured?"

"Here too, the reason is the absence of the Earth's atmosphere. Its ever-changing state affects all rays passing through it: they scatter and a star grows fainter and disappears, then they converge and a bright image strikes the eye, they waver and a star seems to oscillate. All this is impossible here, and we see every star as a bright dot. Furthermore, the thick layer of terrestrial air absorbs and scatters rays which have the highest refractory power—violet and blue—letting through a greater proportion of the red rays which reach the eye of the earthbound observer (this is not so apparent when a star is in its zenith). Thus from the Earth the stars seem reddish, although in a void they are mostly blue, green or the like. Similarly, a cloud observed through a red glass will seem red. Here in the

ether we see the stars in their natural colours, not distorted by the vast two-hundred-kilometre layer of air. As they have different colours, that is how we see them."

"The atmosphere," Ivanov added, "not only scatters and absorbs light coming from the stars, obscuring the weaker stars, it also outshines them in daytime when its light is so powerful that it hides the stars from us. At night this diffused light dims the stars, blotting out the weaker ones completely. That is why we see such a multitude of stars here."

"Why doesn't a spaceman feel any motion in the ether?" one of the workers asked.

"Because there are no manifestations of motion in the ether, none of the sensations that accompany motion on Earth: the resistance of the air, the jolts, jars and vibrations, the fields, gardens and buildings rolling past, etc. We've gradually come to trust our little rocket when we're inside, but outside we still refuse to trust it. This may pass, and then we shall feel our motion not only in the rocket, but in the ether as well. For thousands of years people have never felt the rotational and translatory motion of the Earth and the Solar System. Even now, though we are aware of it, we don't feel it, no matter how we try."

27. DISCUSSING LIFE IN THE ETHER

"If there are no more questions," said Newton, "let's talk about the advantages of life in a void with no gravity."

"The best thing in it is," one of the men ventured, "that you need no effort or muscular power to move about or shift the largest of masses."

"There's no need for trains, ships, horses, airships, aeroplanes, coal, firewood, etc.," another echoed.

"You can travel at tremendous speeds," added a third. "All that's needed is an impulse, i.e., a first thrust. Motion persists, because there's nothing like the resistance of air or water to prevent it."

"Consequently, passenger and goods traffic over any distances and at any speeds costs nothing. . . ."

"Structures of all types aren't subjected to gravitational forces. Walls can be very thin and buildings enormous; gravity can't destroy them."

"How wonderful is the realisation that you can't fall and bruise yourself. There's no danger of falling over a precipice or of a ceiling or wall collapsing. You can't drop or break a plate, and you can work in any position."

"All this is so, but even more important is the profusion of light, solar energy, space. . . ."

"Where are the clouds, dirt, moisture, mist, cold, heat, exhausting labour?" several enthusiastic voices cried.

"Where are the darkness and cold of night, the bitter winds and snows and blizzards, the hurricanes and shipwrecks, the impassable deserts and inaccessible mountains?"

"Gentlemen, your enthusiasm is carrying you away!" Newton said. "All this is so, of course, but we shouldn't let the roses hide the thorns."

"What thorns?" several voices asked.

"I've but to open a porthole or pierce this wall or even accidentally break a glass and we'll all perish without the air, which will immediately escape from the rocket due to its boundless ability to expand."

Many glanced about in terror.

"Our windows are made of thick double glass reinforced by wire mesh. They are sufficiently strong, and yet by carelessness they can be broken. The walls are of metal, but they too can be pierced."

"Let's close our eyes to the negative aspects of our new existence for the time being and turn to the brighter aspects," Laplace intervened.

"The temperature here can rise from zero to 100°C and more," said Ivanov. "All we have to do is to increase the dark surface of the rocket. We can raise the temperature as high as we want to, say, to 25°C. We'll have no need of clothing then! True, our clothes are almost resistant to

wear and tear. The soles of our shoes don't wear out. But we have to move about and operate machines. We can hardly get along without moving at all. This will ultimately destroy our clothing."

The crew decided to reduce their clothing to a minimum as soon as possible, at the same time raising the temperature inside the rocket to 30°C.

"Being so close to the Earth," said Franklin, "we can't achieve very low temperatures: the Earth continuously radiates heat from both its daylight and night sides and warms our rocket. High temperatures, however, are more easily obtained by simply painting the rocket and preventing it from radiating heat. Spherical, parabolic and flat mirrors can raise the temperature to 150°C and higher.

"This will make it possible to operate different types of solar motors, to fuse metals and perform many other technical jobs without the use of fuel."

"With a constant aperture," said Newton, "the temperature in the focus of a spherical mirror (my calculations are based on the works of Stefan) doesn't depend on the size of the mirror. The size only increases the heating surface proportionally. Given an ideal reflecting surface and a black heating surface, a 60° mirror, or a reflecting arc of one-sixth of a circle, can develop a temperature of 4402°C. It doesn't even depend on the distance to the Sun, only the diameter of the focus area expands in proportion to the angular diameter of the Sun, i.e., the closer the Sun the larger the heating surface, the farther the Sun the less the surface. A mirror with an angle of 120° is capable of raising the temperature in its focus to 5000-6000°C. On the Earth half the rays are absorbed by the atmosphere; furthermore, a conic beam is cooled considerably by the air, and we could hope to obtain as much as 3000°C only under the bell of a vacuum pump with glass of an ideal transparency. In normal conditions, of course, we could never achieve such a temperature. However, even platinum melts in the focus of a mirror, which means that on Earth

the temperature in this case is above 2000°C. The heating area, or the diameter of the focus, i.e., the image of the Sun, for a mirror of one meter radius (with an aperture of 60° this will also be the diameter of the mirror) is four millimetres. If the mirror diameter is increased tenfold, the focus area will correspondingly increase to four centimetres. Here in vacuum we can probably obtain a temperature of five or six thousand degrees. We could raise it even higher by special methods, but there is no need for this."

"Which means," Ivanov remarked, "that we have excellent facilities for sundry metal-working jobs—in the space outside the rocket, of course, and wearing space-suits. When we work in the atmosphere the air attacks metals and tools and damages the products of our labour. Here welding, for instance, is very simple: all we have to do is to concentrate a beam of light on the welded parts and fuse them with a rod of the same metal, or even just joint the heated edges. The focus and temperature can be controlled with great precision. Why, it's wonderful!

"And we shouldn't forget," he went on, "that, here, mirrors won't become deformed under their own weight, they can be transferred and revolved in their light frames without effort and their surfaces won't oxidize and grow dim. Marvellous! Why, a mirror even 1,000 metres across is quite feasible, and such a mirror will produce a four-metre focus. How do you like that? But even with a small mirror we can consecutively weld together large surfaces."

"You have again mentioned the absence of gravity," an elderly worker intervened. "Of course, it is indubitably absent, since I simply can't feel it, and yet I don't understand it: the Earth is so close, its gravity is practically the same, so why don't we feel it?"

"I've already explained," Newton said. "But let's approach it in another way: do the people on the Earth feel the attraction of the Sun and the Moon? It exists, but no

one feels it and even scientists don't take it into account. It is manifested only in the ocean tides. The gravitational force on any planet and on satellites depends only on its mass. Even the most exacting astronomers ignore the influence of the mightiest of suns. In our rocket, too, gravity depends only on the mass of the rocket, its shape, etc. And since its mass is negligible compared with the mass of a planet, its attractive force is also negligible."

"And yet," another elderly worker remarked, "the absence of gravity has its drawbacks, and sometimes it's a downright nuisance. All sorts of odds and ends are drifting about the rocket, dust doesn't settle—how are we to wipe it away? Water refuses to stay put in open vessels, you can't take a bath or wash, and in the lavatory it's just awful. . . ."

28. TAKING A BATH

"First of all," Laplace said, "the air in the rocket is continuously pumped through special filters and all impurities are removed. There may be a pencil or something drifting about, but that's due to our own carelessness. Secondly, you've probably had no occasion or time to take a bath in our specially equipped bath-room."

"True, I haven't had a chance to take a bath yet," the stout man said, good-naturedly.

"Our bath," a young worker said, "consists of a sealed cylindrical tank three metres in diameter with one entrance, which rotates about its axis. The tank is half filled with water. To take a bath you set the tank rotating. The water flows to the walls and makes a cylindrical surface of uniform depth. Thanks to the centrifugal force bathers can stand chest-high in the water, their heads pointing towards each other like the spokes of a wheel. There are several windows and various devices and you can have an excellent bath."

"You don't say! And here I've been wanting a bath so much. . . ."

"That's always possible," the young worker said.

"Furthermore," Laplace continued, "who's to stop us from generating gravity in the whole of the rocket by revolving it as we've already done. We can maintain artificial gravity as long as we want to, at practically no cost. Gravity can also be developed in any structure outside the rocket. When we spin a vessel of water, or rotate vanes submerged in it, the water will accumulate round the equator of the vessel and remain there. Revolve this pot and you'll see that the liquid won't pour out. The simplest thing is to close a vessel tight and stir the liquid with vanes whenever you want it to pour. All you have to do is open a tap and a fountain of water will gush out."

"We've been bathing quite often," one young man remarked, "and I must say I enjoyed it very much. How is it that the water is always so pure? Is it changed often? For we cannot have unlimited supplies of water!"

"It's continually being purified by distillation, filtration and by other physical and chemical methods," said Ivanov. "It is also disinfected by heating and other means."

29. SUMMING UP LIFE IN THE ETHER

"I should like to sum up our talk," Newton said after a pause. "Thanks to the Sun we have the temperature we want and can therefore get along without shoes or clothing; this is further facilitated by the absence of gravity. Weightlessness also provides us with the softest of quilts, pillows, beds, etc. To it we owe the ease with which we can cover long distances quickly and effortlessly. We shall also be completely provided with food and air when we have built several greenhouses. If the yield from the plants we have with us were absolutely perfect the existing surface of the rocket would be sufficient. The space we could occupy round the Earth, at only half the distance to the Moon, receives a thousand times more solar energy than the terrestrial globe does. I imagine that this space or

ring, which explorers after us will in time occupy, be perpendicular to the Sun's rays. It is already ours, and we have only to fill it with dwellings and greenhouses, and to populate it. Parabolic mirrors can produce temperatures up to 5000°C, while the absence of gravity makes it possible to build mirrors of practically any size and, consequently, to obtain heating areas of any size. High temperature and the chemical and thermal energy of sunlight not weakened by the atmosphere make it possible to carry out a wide range of industrial jobs such as, for instance, welding, reducing metals from ores, forging, casting, rolling, and so on. True, we lack terrestrial variety, the romance of highlands and oceans, storms, rains and frosts. On the other hand, we're not quite deprived of the Earth," Newton went on, pointing to the visible contours of the seas and continents. "Yet to most of the mortals on our planet, all that romance is nothing but a source of annoying, often cruel and distressing cares. Nevertheless, the Earth remains ours and it will always be ready to embrace people who find separation from it unbearable. In short, we can always return to it. But do we really lack romance here? We have left to us science, matter, worlds and mankind surrounding us on all sides in this boundless space! Is not Man himself a being of the loftiest romance? Is not the Universe more accessible to us from here, than from the Earth?"

"That's all very well," said Ivanov, "but now allow me to list the shortcomings of this world. The vicinity of the Earth robs us of a simple means of obtaining the low temperatures required for the more efficient work of our solar motors, for such industrial purposes as the liquefaction and solidification of gases for storage."

"That handicap is easily rectified," Newton remarked. "All we have to do is travel away from the Earth. We can even obtain much more space and sunlight if we set up our new dwellings in a ring about the Sun extending beyond the Earth's orbit. There we can receive thousands

upon millions of times more energy than the Earth receives. The temperature can easily be lowered to almost absolute zero."

"Certainly," Ivanov agreed. "The absence of low temperature is easily remedied. But I could point out other negative aspects of our life here. True, we have no need of clothing and furniture, but then, we are confined to a dungeon, light and beautiful though it may be. We can leave it only in space-suits, which are complex apparatuses and much more cumbersome than clothes."

"Space-suits," said Franklin, "serve one single purpose and are needed to overcome one single obstacle. They are essential here to one and all. The manufacture of hundred millions of one single item will reach perfection and become inexpensive. In this respect the space-suit cannot be compared with clothing. But here our dwellings also take the place of clothing. And dwellings here can be furnished very simply and with great uniformity. We can therefore say that once we have dwellings, there is no need to have clothing."

"That's so," the Russian said, "but in these dwellings we are constantly exposed to the risk of losing gas and perishing!"

"Dwellings will be as uniform as clothing. When built for hundreds of millions of people they will be improved to perfection. The environment is extremely uniform, which makes it possible to perfect them in the same way as the space-suits. Besides, doesn't everyone on Earth risk his life every minute of the day even now? If the heart is pierced, a vital ganglion injured, the carotid damaged or the aorta severed, you'll die. Here, though, the surrounding population will be so numerous, so wise and united and will have such remedies, such instruments, that it will always be possible to find a means of counteracting any danger or misfortune.... I can't forecast all the possibilities of improvements in the next millenium," Newton said with some heat.

"Maybe mankind will so evolve that in the void it will need neither space-suits nor shelters," Franklin noted.

"Or it may create even earlier a gaseous, unenclosed atmosphere in the ether!" the Russian added.

"We can hardly hope to interpret all the ideas we have," Laplace concluded.

30. DESCRIPTION OF A BATH

"Gentlemen, that's enough. Let's refresh ourselves with a bath!" one of the listeners exclaimed.

The suggestion was approved and several members of the crew pushed off and flew to the bath-house compartment. They found there a large drum about four metres long and three across occupying almost the whole of the compartment. First they made it turn about its axis. In the absence of gravity the drum revolved by inertia and only a slight impetus was needed to keep it turning. On one side of it, at the drum axis, was a hatch about a metre in diameter which they opened. Divesting themselves of their colourful loin-cloths and loose-flowing robes—a very light and unburdensome costume—they plunged one after another into the bath. Revolving together with the drum, the water spread over its circumference, with the cylindrical surface as the bottom. Pushing and jostling, our companions dived into the water. They began revolving together with it and regained their weight. With what satisfaction they soused themselves in the cool liquid! How easy it was to swim there! Ivanov saw Newton directly overhead, ducking and splashing with the same delight as he, with Franklin alongside and the others at right angles. To see Newton, Ivanov had to lean back as if inspecting a church dome. The men stood with their heads towards each other and their feet away. This was the only peculiarity of their bath. In other respects it was just like one on the Earth. They ducked, dived, caught one another by the feet, splashed about, swam this way and that,

agitated the water, shouted and laughed and, most important, felt splendidly refreshed. The artificial gravity was not great. What need had they for more? Hence, it was much easier to swim here than on the Earth. All the hydrostatic and hydrodynamic laws based on gravity, such as Archimedes' law held good again. After revelling to their heart's content, the company flew out of the bath just as they had entered it. There was no need to dry themselves: the hot sunlight, which shone continuously through the thick foliage, dried them rapidly. They put on their loin-cloths and went about their private affairs. The water was filtered and the residue from the filters was used for fertilising purposes.

31. THE GREENHOUSE

The next meeting was opened by Newton, who reported on the existing state of affairs.

"Gentlemen," he began, "I should like you to pay attention to our domestic affairs. Our supplies are steadily dwindling. They are turned into fertilisers for the plants, but we aren't growing enough fruit and vegetables to utilise all the fertilisers. The rocket is too small for the purpose. We have to add a greenhouse, then we'll have more space to move about in without getting into our space-suits. We shall no longer use up our supplies of oxygen and food: the surplus plants will provide us with both. All excretions and waste products will be completely absorbed. We shall get from our plants as much as we give them. There will be no need for us to husband our supplies, for we'll be adequately supplied with carbonaceous and nitrous substances from the fruit we grow. Having in view the easy life we have, the absence of arduous labour, and the thirty-degree temperature, such a diet is both wholesome and necessary."

"Wouldn't it be better," Laplace suggested, "to set up greenhouses separately from the rocket? Plants don't re-

quire as much gas, and an environmental pressure as we people do. Their atmosphere can be different and made to have an excess of carbon dioxide, moisture, and so on, all of which is unsuitable for human beings. The greenhouse may be limited in size to that of a pipe two metres across: just large enough for a gardener to fly through it freely in order to tend the plants and collect the fruit. This and the low density of the surrounding gaseous medium will make it possible to effect a considerable saving in building materials, our stocks of which are not endless."

"I fully agree," Newton said. "If I'm not mistaken, the sections of the greenhouses are almost completely prefabricated and they are built precisely on the lines just described. We'll have adequate space inside the rocket, and if anyone feels cooped up, there's nothing to stop him getting into his space-suit and gallivanting for hundreds of miles around. The rocket itself, thanks to its exhaust nozzles and its tremendous stocks of propellants, can be steered away from the Earth to the Moon or asteroids or wherever we wish to go. We are journeying at this very moment and beautiful, changing pictures of the Earth are forever unfolding before our eyes. One might say we were travelling in eternity. As for the greenhouse, we'll connect it to our rocket by two narrow tubes: one for removing carbon dioxide and other human refuse from the rocket to the greenhouse, the other for delivering the fresh oxygen exhaled by the plants to the rocket. We'll need pumps, but our solar motors brought from the Earth work excellently."

"Gardening will be a wonderfully simple job here," Franklin said. "The soil was baked to destroy all weeds, harmful bacteria and pests. As to useful bacteria, for leguminous crops, for instance, we'll introduce them ourselves. Thus there will be no need to weed our garden. All we'll have to do is look after the composition of the soil, the moisture and the gaseous atmosphere.

"The liquid and soil for the plants is prepared just be-

fore planting. The garden will be irrigated automatically. Water will be condensed from vapour in specially designed cold sections of the rocket and pumped to the consumers. Flowers will be pollinated almost instantaneously with the help of air fans. The atmosphere will be produced by our breathing. Finally, the fruit will be touched by no disease and will grow in all directions without weighing down the plants, as there is no gravity."

"But won't we have to leave the rocket to get to those separate structures?" one of the workers asked.

"Of course," said Newton. "Don't you like the idea?"

"On the contrary, I'd like very much to have a jaunt outside the rocket," the same voice replied. "I haven't been there yet."

"We'll all have to go out to work," said Newton. "Besides, we shall frequently have to visit the new greenhouse to bring in the harvest and look after the plants, and we'll have to wear our space-suits for that, since the gas pressure in the greenhouse will be too low and the atmosphere unsuitable for human breathing."

32. BUILDING A GREENHOUSE. INEXHAUSTIBLE SUPPLIES

Several hours later they began building the greenhouse. They unpacked the structural elements, mainly thin cylindrical tiles of a specially strong and resilient glass reinforced by rectilinear wire netting. There were spherical parts, finished metal attachments and very thin metal sheeting. The materials were placed in a special chamber, the air was evacuated, a hatch opened and the materials pushed out into ethereal space.

Large sections were simply leashed to the rocket, smaller ones were stored in a special spherical wire cage outside. Once inside the cage, the objects wandered back and forth like beasts and would not settle down for a long time. The cage, of course, was strapped to the rocket and had a door and lock. The structural elements were all

numbered and ten workers assembled them in a matter of hours. The workers left the rocket as described before. At first they moved about very clumsily but they soon grew accustomed and proceeded with their job. They couldn't help glancing down apprehensively to where the void yawned underfoot. The work was very easy: no matter how heavy an object it could be moved by the slightest effort. However large, thin or weak the various parts, once they were joined, but slightly, they neither separated, fell, deviated nor bent. A senior worker supervised the construction. Elastic strings stretched between the men made it possible for them to converse among themselves, or even all at once, with the usual confusion which results in such cases. Vibrations caused by the vocal chords were transmitted through the air in the helmet to the space-suit, to the string, and through it despite the surrounding void to some else's space-suit.

The shell of the greenhouse was soon assembled, but the parts had to be welded together to prevent gases from escaping at the joints.

The welding, that is to say the sealing of the transparent and opaque sections, was an exceedingly simple matter. The workers could surround the greenhouse on all sides, and all postures were equally convenient to them. They stood parallel or perpendicular or at an angle to the structure, swarming over it like flies. For welding, however, the greenhouse had to be placed in a special position in relation to the Sun, for the work was carried out in the focus of parabolic mirrors. The job was like gas-welding on the Earth, only more simply and perfectly performed, in the absence of oxygen and combustion, and because the workers were not compelled to adopt inconvenient, unnatural positions. The temperature was higher and more stable. In short, it was more like play than work. Only the frequent setting of the Sun 67 minutes after it had risen, interrupted their work. But even when the Sun disappeared, the Earth, which occupied one-third of the sky (120°),

provided both light and warmth and they could continue to work during the night on jobs not requiring the Sun's heat. The constant switching from one kind of work to another was, however, irksome; the men were unwilling to interrupt the work, which was going so well. But half an hour (33 minutes) later, the Sun would come again to their aid in all its grandeur.

Soon the welding was completed, and tested to ensure that it was air-tight, all the cracks and fissures detected were sealed, and the walls were declared to be completely air-tight. The greenhouse was a cylindrical tube 500 metres long and two metres across. A huge window occupying one-third of the circumference extended from end to end. Flattened out, the window was 500 metres wide and two metres high. In spite of its size, the pipe was not massive, but it was strong, flexible and durable. Although there was a possibility of breaking the glass, though only with great difficulty, this would not let the gas escape thanks to the strong metal reinforcing netting of the glass which prevented it from splintering. Small fissures were gas-tight. The wall, if struck, only vibrated elastically. The workers in their space-suits swarmed over the finished hull. When they bumped into one another, they tumbled about comically, and then calmly restored their equilibrium. They critically surveyed their handiwork from all sides and at various points distant from it.

Lastly it was necessary to bring into the greenhouse a vessel containing a semi-liquid soil, let in the rarefied gases, plant the seeds and regulate the temperature, humidity, fertilisers and the composition of the gas-forming environment.

A sectional, opaque, metal vessel was installed, extending the whole length of the greenhouse along its axis. It was filled with a soil-and-water mixture and had many little holes in which seeds or seedlings were planted. Inside, its walls were moistened with a liquid, while on the outside, they were coated with a special enamel. Thanks to

this the liquid could not leak outside and in accordance with well-known hydroscopic laws remained confined inside the central pipe. Two thin tubes passed down the middle of this pipe with rows of holes in them. One supplied gases to the soil, the other liquid fertilisers. Perpetually operating air pumps produced the required gas mixtures which permeated the soil. Other pumps delivered to the soil liquid containing fertilising substances.

You may be astounded that such an enormous greenhouse could come out of the rocket. But, firstly, its volume was almost equal to the volume of the rocket; secondly, the pressure of the gases and vapours in the greenhouse was so small that its walls could be very thin, no thicker, in fact, than ordinary cheap window glass. Thus, the whole shell weighed some 20 tons, whereas the rocket and its pay load weighed 400 tons. The greenhouse provided an additional 1,000 square metres of surface exposed here to strong sunlight throughout two-thirds of the day, that is, 50 square metres per person! It is not difficult to imagine what a tremendous amount of nutritious fruit could be provided by that surface up here, in these wonderful growing and lighting conditions! The glass was of pure quartz which lets through chemical rays greatly intensifying plant development and good yields.

Finally everything was completed, the seeds planted and the greenhouse began to function. Shoots soon appeared. The transparent part of the greenhouse was continuously set perpendicular to the Sun's rays. The back surface was twice as large, but as it reflected diffused sunlight, it lit up the whole shaded part of the central pipe with its delicate sprouting leaves. Nevertheless, the distribution of light was uneven and the soil pipe was turned so that the young plants would receive equal quantities of solar energy. The rotation was automatic, though it could be done by hand without leaving the rocket. In general, the fertiliser supply, lighting conditions, etc., could be controlled from inside the rocket, so there was no need

to get into space-suits very often. It should be noted that both the rocket and the newly constructed greenhouse were always orientated most advantageously in relation to the Sun. This could have been achieved by keeping a constant sleepless vigil, but a more convenient solution was found. Light is known to exert a slight—very slight—pressure on bodies, amounting to half a milligram per square metre of a surface. By itself this force was too weak to turn the rocket, but it performed the same service as a ship's compass. An even simpler device was a magnifying lens attached to the greenhouse wall so that it cast a bright, hot spot on a screen placed in its focus. Any deviation by the spot from a specific point set in motion the attitude-control mechanisms of the greenhouse which returned it to the required position. An even simpler method of attitude control would have been to make the rocket and greenhouse revolve gently about some axis.

Strawberries, various vegetables and fruit grew by the hour. Many plants yielded every ten or fifteen days. Dwarf apple- and pear-trees and other diminutive fruit-bearing shrubs and trees were planted. They blossomed continually and bore amazingly large and tasty fruit. Some trees blossomed while others were already carrying ripe fruit. The most successful crops were water-melons, musk-melons, pine-apples, cherries and plums. It was only necessary to prune the growing shrubs and trees very often. The harvest was picked continuously, as there reigned an unchanging climate with no seasons. They could artificially change the climate over a broad range, making it possible to grow the sort of crops to be found in the different countries of the Earth. Large trees were impossible, both because of the limitations on size imposed by the dimensions of the greenhouse and the shortage of soil and fertilisers. When millions of human beings inhabit these empty ethereal expanses matters will be arranged differently.

The space travellers frequently visited the greenhouse to collect fruits or simply for the sake of an outing. They

had to wear space-suits for these excursions, as the pressure of the gases and water vapours in the greenhouse was not more than 20 millimetres of the mercury column, i.e., one fortieth of atmospheric pressure, which is totally inadequate for human beings. The composition of the gases, which completely suited the plants, was wholly unsuitable for human breathing. The humidity was far below the saturation pressure corresponding to the temperature because the vapour from the leaves and soil was condensed, before it could reach saturation point, in special appendages of the greenhouse, which were kept constantly in the shade and where consequently the temperature was close to zero. Thus the vapour pressure was never greater than 4-10 millimetres. Carbon dioxide, oxygen, nitrogen and other gases were also in an extremely rarefied state. But this, it is known, hardly affects plant development.

Thus, on Earth the content of carbon dioxide—the principal gas for plants—does not exceed one-thousandth, i.e., the partial pressure is not more than one millimetre.

The crew took great delight in visiting the greenhouse, especially at first. The plants grew so thick that they could hardly make their way through the lush vegetation. Flying along the tube they had to keep their bodies parallel to the walls in order not to touch the fruits. This sometimes happened, for all that, and much of the ripe fruit came away from the plants. They would never have come away of their own accord, no matter how ripe, for they had no weight. Even when separated from the plants, the fruits did not fall, but drifted about until they got caught in the dense foliage. A spaceman, flying about like a bird in the greenhouse could simply have caught the fruit in his mouth, but unfortunately the space-suit made it impossible. The fruit and berries bounced off the helmet and had to be caught in a net like butterflies and stored away in light, semitransparent bags.

Access to the greenhouse was not simple, despite the

space-suits. To pass inside from outer space one had to enter a special air-lock and close the outside door. Air from the greenhouse was then let into the lock through an open hatch through which the person entered the greenhouse.

Later, when an air-lock was made to connect the rocket and the greenhouse, the whole procedure became simpler. Anyone dressed in a space-suit could enter the lock with the atmosphere of the rocket. Then the air was pumped into the dwelling section, the second door was opened, and the person entered the greenhouse. If he wished to go from the greenhouse into outer space, he entered the outer air-lock of the greenhouse. The gases and vapours in the lock were pumped back into the greenhouse, the door into ethereal space was opened, and the spaceman flew out.

33. CAREFREE LIFE. SOLAR TELEGRAPHY

Our travellers were now established comfortably. They had consumed their stores but had no further need for them as the greenhouse produced an abundance of tender, fragrant fruit and vegetables, containing sugar and oil. The more they ate the more fertilisers they had and, consequently, the more food they could grow—to the extent, of course, allowed by the solar energy falling on a unit of surface. Their bodies spent so little energy on movement and protection against cold that they put on weight in spite of their vegetarian diet. They enjoyed the "featherbed" state of their gravity-free environment and the absence of diseases. Diseases and their infecting agents had no opportunity of developing in the rocket, and even if some bacteria were to make their appearance, the fierce rays of the Sun would destroy them all. The only area not completely disinfected was the inside of the human body!

Being completely provided for, they could have continued in their blissful state until death if death had any power there.

They had a rub-down or bathed almost every day. The bath was easily transformed into a shower, and artificial rain produced by centrifugal pumps driven by solar motors sprayed abundantly from all sides of the bath-house.

The tranquillity of their life, however, brought boredom. They searched for new activity. It was necessary to send to Earth a detailed report on their condition, work, achievements, and state of mind. Most of the electric-power reserves had already been exhausted and other means of telegraphy had to be devised.

Ivanov estimated that solar light reflected by a flat mirror was 40,000 times more powerful than light scattered by a ground glass surface in similar conditions. There was sunlight in abundance and plenty of mirrors. One square metre of mirror reflected as much light as a silver-backed ground glass 200 metres square. At a distance of 1,000 the brightest planet reaches only 0.6 of a minute at its closest opposition, and then only a narrow crescent is seen. Clearly the mirror could be observed much better than Venus in the most favourable conditions which meant that it could be seen even in daytime. The best time for reflecting the light was just before sunset and immediately after sunrise, and this happened twice every 100 minutes, which was the duration of a day and night up here. Long and short flashes were produced by manipulating the mirror slightly. The flashing of the new star could be observed from parts of the Earth immediately below and the Morse signals readily deciphered.

34. MANKIND IN THE YEAR 2017*

What was our Earth like in the year 2017, to which our narrative relates?

There was a single authority for the whole world, a congress of elected representatives of all nations. It had

* Written before the 1917 Revolution.—*Ed.*

been inaugurated more than 70 years before, and it dealt with all mankind's problems. Wars were impossible. Misunderstandings among peoples were settled by peaceful means. Armies were drastically limited, or rather, they were labour armies. Thanks to the fairly favourable conditions of the preceding one hundred years, the population had trebled. Commerce, engineering, the arts, and agriculture had progressed considerably. Huge metal airships capable of lifting thousands of tons made travel and goods traffic both convenient and cheap.

Especially effective were the largest airships, which by using air currents were employed to transport almost free of charge such inexpensive commodities as wood, coal and metals. Aeroplanes were used for the rapid transport of small numbers of passengers or valuable commodities. Most widespread were single- and two-seater aeroplanes.

Mankind was peacefully advancing along the road of progress, but the rapid growth of the population was a matter of concern for all thinking people and rulers.

Ideas about the technical feasibility of conquering and exploiting the deserts of the Universe had been voiced more than a hundred years before. In 1903, a Russian scholar wrote a serious work on this subject and proved mathematically, on the basis of the scientific data available at the time, the feasibility of colonising the Solar System. His ideas, however, were all but forgotten, and it was left to our company of scientists to revive them and partially carry them out.

35. THE STRANGE STAR. THE WORLD LEARNS THAT THE DESERTS OF THE UNIVERSE ARE OPEN TO MANKIND

Many people observed an unusual phenomenon which recurred before dawn and at dusk: a bright flashing star travelling rapidly across the sky. At first it was thought to be an airship, signalling with an electric light, but it was pointed out that an airship would have several bright, un-

blinking lights at night. Furthermore, the deciphered signals carried an amazing message.

Rumours had it that a space vehicle based on the rocket principle had departed from the Earth, but the news had been ridiculed as merely another newspaper sensation. Then one day the following telegram was deciphered:

"April 10, 2017. On January first, this year, we the undersigned, 20 persons in all, took off in a reaction-propelled vehicle from a valley of the Himalayan Mountains (name supplied). We are now circling the Earth in our rocket at a distance of 1,000 kilometres, making one complete orbit every 100 minutes. We have built a large greenhouse, planted fruit and vegetables, and have already gathered several harvests. Thus we have plenty of food and are alive and healthy and adequately supplied for an indefinite period of time. We are surrounded by boundless space capable of providing a home for countless millions of human beings. We invite you to move up to us if you are inconvenienced by overpopulation and if terrestrial life burdens you. Here life is a virtual paradise, especially for the weak and ailing.

"Details of our flight can be obtained from our place of departure, where full information about our achievements is available. There you can obtain the necessary information about the construction of reaction-propelled vehicles for space flight." The telegram was signed by several famous names.

The report was received by many telegraph operators and printed in all newspapers. Everyone had seen the wonderful flashing star. Scientists and academicians studied it. They determined its distance from the Earth, the time when it appeared, the elements of its orbit, its velocity, etc. Their data confirmed the authenticity of the telegram, for no airship could rise to an altitude of 1,000 kilometres in order to hoax the world. A wave of excitement spread over the Earth as if the end of the world had been an-

nounced, but this was joyful excitement. What prospects were now thrown open to the human race!

People of every nationality knew, besides their own tongue, a universal, world-wide language. There was a common alphabet, certain common laws which united people possessing the most diverse qualities and natures. News of the world-shattering events spread rapidly to the farthest corners of the Earth. Airships delivered newspapers, books, preachers and lecturers at very low expense, often just with the aid of a fair wind.

Everyone participated actively in terrestrial affairs. The announcement of the accessibility of the deserts of the Universe was hailed with great delight, for many people had been longing for the freedom of outer space. The ailing hoped to be cured, the old and the weak, to prolong their lives. Our Himalayan anchorets were the centre of interest, a source of happy news and information, towards which the eager ears of the world were ever turned.

Countless commissions from scientists and engineers were dispatched to our hermits in order to investigate their work on the spot. A vast number of schools were opened for studying the sky and reaction-propelled vehicles. Graduates from these schools qualified as reaction-propulsion engineers. Factories were built for the manufacture of space projectiles. Technicians, foremen and workers were trained. In short, the wheels were spinning, and in less than a year a thousand reaction-propelled vehicles were ready for the transmigration.

36. BEYOND THE EARTH AGAIN. DISCUSSION OF A NEW SPIRAL FLIGHT ROUND THE EARTH. THE MYSTERIOUS KNOCK. A WATCHMAN IN ETHER

But what were our rocket men doing meanwhile? Several months passed before the curiosity of mankind was satisfied. Daily they received hundreds of questions from the Earth which had to be answered. Finally, the curiosity

began to abate and a telegram as follows was flashed to the Earth: "Are travelling in spiral path away from the globe. Will explore the space area round the Earth. Expect no telegrams meanwhile."

Once again the crew assembled in the drawing-room. Newton opened the meeting.

"We've reported all our experiences to the Earth, what we have felt and have found. Let the inhabitants of the Earth make use of these expanses, this sunlight and warmth, this carefree, affluent social existence and the opportunities it provides for unhampered thought and enterprise. We have supplied the technical data necessary for organising an exodus and forming a colony round the Earth. There is nothing to keep us here any longer, but it would be a good idea to pave the way for the further advance of mankind."

"Hurrah! We're flying on!" enthusiastic cries welcomed his words.

"But, in effect, we haven't even explored the space round the Earth as far as the Moon's orbit. This is a vast region which receives thousands of times more light than the Earth. We shall place it at the disposal of man. The rocket and the greenhouse with its continuously ripening fruit provide us with everything, from the material point of view," Newton continued. "We can't part with the greenhouse and will have to drag it along on our spiral journey."

"We'll switch on our motors," said Laplace, "and the rocket will take the greenhouse in tow."

"Here we won't need a powerful thrust," Ivanov remarked. "Before, our acceleration reached 100 metres a second, which increased our weight tenfold, compared with the Earth. This forced us to submerge in water to protect ourselves. Now a thrust of one ten-thousandth is all that is necessary and adequate. An acceleration of one centimetre per second will be enough."

"The relative gravity," Franklin commented, "will be one-thousandth of the terrestrial gravitational force, i.e.,

quite negligible. It can't harm the greenhouse or the plants in it, to say nothing of the rocket, which can withstand large loads."

"In fact," Laplace remarked, "our flight will hardly affect our present state. In the rocket and the greenhouse we shall fall in the direction of their long axes. A falling body will travel five millimetres in the first second; it will take ten seconds to fall 500 millimetres, or half a metre, and one hundred seconds to fall 50 metres, or half the length of the rocket. We'll be able to enjoy standing and walking, although we shall find it rather difficult. A sneeze, a cough or a sudden wave of the hand or foot will waft us off our feet. A man weighing 100 kilograms will weigh only 100 grams. Of course, the objects, plants and people lashed secure in the rocket and greenhouse will remain in place. We'll continue to fly about without even noticing the slight weight we possess."

"The purpose of this small acceleration," said Newton, "is to describe a spiral about the Earth and explore the surrounding space as carefully as possible. Our spiral motion will carry us farther and farther away from our planet towards the Moon's orbit. We can't have a great acceleration or thrust force as, in that case, the greenhouse would be destroyed by its own weight. We could dismantle the greenhouse and stow it away in the rocket, but this would be a nuisance and we should lose too much time. Besides what would we eat? We have no more stores, and a final harvest before dismantling the greenhouse would last no more than a fortnight. We'd probably spend more than that on dismantling, re-assembling, planting, and waiting for the fruits to ripen.

"Even this acceleration of 1 cm/sec is a lot," Newton continued. "It will take 200,000 seconds, or about a day and a half, to increase the rocket's velocity by one kilometre per second. In the meantime the rocket will have circumnavigated the Earth more than ten times and travelled a considerable distance away from it. Due to the

increasing distance from the Earth, the actual velocity will gradually decrease, and near the Moon's orbit it will be only one kilometre a second, as compared with 7.5 now. By then we shall have almost completely overcome the Earth's gravitational pull. Furthermore," Newton concluded, "if we find it necessary we can stop the motors or we can accelerate the rocket."

"Why not fly straight from the Earth round the Sun?" one of the crew asked. "What can we expect to find in the neighbourhood of the Earth? Isn't the space round the Sun and onwards to the orbit of Mars and the minor planets more interesting? If anything, it is a million times greater than the Earth-and-Moon backwoods!"

"Why, listen to him talk!" several voices exclaimed. "He calls an area a thousand times greater than the surface of the Earth mere backwoods!"

"A trip round the Sun independently of the Earth is possible," said Franklin. "But caution is the best counsel. No harm will be done by exploring the neighbourhood of the Earth more carefully. We want to know whether it is suitable for life and whether there are bodies in it that might endanger the colonies of man. We'll have time enough for the other trip. At present we are more interested in the neighbourhood of the Moon. We may even visit it."

"How interesting! That's really something!" several excited voices exclaimed.

All of a sudden a loud knock echoed through the ship. Everyone looked around.

"Gentlemen, who did that?"

The sound was an unusual one, rather like a bump from outside. Some grew pale, others hastened to the portholes.

"Gentlemen!" one of the latter exclaimed. "A strange object is receding from the rocket. Maybe it hit us and rebounded?"

The others peered out.

"Why, it's an aerolite!" Ivanov exclaimed, "a celestial rock, a tiny planet or part of a comet."

The rock was slowly drifting away and dwindling in size.

"By the time we get into our space-suits and fly out," Newton observed, "the bolide will be too far away and we may not find it."

"I think it would be a good idea to keep a lookout near the rocket," Laplace suggested. "We really ought to capture a body like that. The material may come in handy. The iron, nickel, carbon, oxides and other substances contained in these roving rocks can all be utilised."

The suggestion was accepted, a schedule was drawn up and one of the crew left to go on watch.

"I think the rock which alarmed us so much is a satellite of the Earth," Newton said. "The blow was relatively weak, which may mean that it is one of the Earth's little moons revolving round it with a velocity corresponding to the distance. The velocity should be very much like that of the rocket, making the relative velocity of the rocket and the rock almost zero. Such celestial bodies present no danger to us since collision with them will be slight. Comet bolides, however, may well destroy the rocket and the greenhouse. This collision of ours is an extremely rare thing and the probability is no greater than the chance of an aerolite falling on a house on the Earth. We have as much cause to fear such a collision as to expect a bolide to fall on the head of a chance pedestrian on the Earth. We shan't need watchmen to look out for such a contingency. On the Earth no one lives in fear of an aerolite. However, our watchman might be lucky enough to spot in a telescope some large body several hundreds of kilometres away. Then we could capture it and make use of the material."

"If there's no danger," said Ivanov, "do we really need a watchman? We can keep a lookout in all directions from the inside using spyglasses. There'll be plenty of enthusiasts. As it is, we are always staring out into space. If

anyone notices something of interest a trapper can immediately set off after our celestial quarry."

The watchman was called in, and he was not at all displeased.

37. SPIRAL FLIGHT. TRAVEL IMPRESSIONS. BOLIDES. REACHING THE MOON'S ORBIT. DECIDING TO LAND ON THE MOON

Two symmetrical exhaust nozzles were used and the expenditure of propellants was reduced to a minimum.

The blast was hardly noticeable and soon everyone grew as accustomed to it as to the ticking of a clock. They looked out of the portholes with curiosity. They saw the same black sky, the huge crescent of the Earth, the gleaming bluish Sun, the dark sphere powdered with the silver dust of unblinking stars. At first they were amused by the sensation of gravity and falling, to which they had grown unaccustomed. But the falling was negligible and it had practically no effect on their usual flying about and gambolling in the rocket. Water poured into vessels from a slow-running jet, forming a horizontal surface over which large waves rolled lazily. Pendulums swung astonishingly slowly: the pendulum clock in the rocket went 32 times more slowly than one on the Earth.

Previously, when anyone left the rocket in his spacesuit and took care not to push off, he hovered near it; if he pushed off he moved steadily away. Now, he fell away from one end of the rocket and was pressed against it at the other end. The same occurred inside the rocket: in one hundred seconds a person, like any object, fell 50 metres from it, in one thousand seconds the distance reached five kilometres. The velocity grew in proportion to time. This was no joke and made a leash necessary. It grew taut, but hardly perceptible. If a person jumped forward from the front end of the rocket he soared up with uniformly-retarded motion, the retardation being one-thousandth of the

magnitude of retardation in conditions of terrestrial gravity, and finally returned back to the rocket. The thrust could be increased and the phenomenon would be more pronounced. A large gravitational force, however, could damage the greenhouse.

"It seems to me," said one of the bolide searchers, "that the Earth and the continents and seas are growing smaller."

"That is the natural consequence of our spiralling away from the globe," Ivanov remarked.

The days grew longer but the nights, while increasing absolutely (due to the slower motion of the rocket) became shorter as compared with the days. With each circle around the Earth the splendid evening glow, a crimson circle embracing almost the whole sky, grew smaller and weaker. It was quite light, but not as before. The Sun shined as before.

All twenty men maintained a continuous watch, with weak and powerful telescopes from the well-polished portholes of their cabins. They began to meet small bolides several centimetres in diameter, but they made no attempt to catch them as they were too far off. Soon there were more of them, some hardly moving. This meant that their motion coincided with that of the rocket, i.e., it was in the same direction and almost of the same speed. They were caught and moored to the rocket. Not a single bolide, however, came closer than within several kilometres. The men chased them in space-suits fitted with small jet motors and caught them in nets. Soon a sizable collection was assembled. Analyses revealed the presence of iron, nickel, silica, alumina, calcium oxide, feldspar, iron chromite, iron oxides, graphite and other simple and compound substances. The most frequently occurring were pure iron, nickel and silicon.

Newton showed the company a collection of uranolites and informed them of the results of the analyses.

"We have here," he exclaimed, "excellent building ma-

terial, the oxygen we lack, and soil for plants. True, the oxygen is in combination with other substances, but it is there and nothing could be simpler than to extract it in gaseous form. After all, we have such a powerful source of energy as the Sun. The temperature in the focus of our mirrors can reach 5000°C.

"We've lost very little oxygen and water vapour," Laplace remarked.

"Water, too, can be obtained from these rocks," Franklin observed. "Some of the feldspars contain chemically combined water."

"It is noteworthy," said Ivanov, "that all these minerals and elements are familiar to terrestrial mineralogists, since they are present in the rocks of our native planet. They have also been found in aerolites collected on the Earth and kept in museums."

"If the composition of this world is so like our own," Ivanov went on, "what is to prevent it from becoming man's habitation and an arena for his activity?"

The farther they receded from the Earth, the more rocks they encountered. Some of the bolides were several metres across, but they left such giants alone as their bulk would hamper the motion of the rocket. Sometimes a shadow would flit by in the distance: these were splinters of comets travelling at terrific speed. The larger and more distant bodies travelled across the black sky like stars, though they were much closer. Most bolides between the Earth and the rocket moved faster than the latter, those farther away moving more slowly. The illusion was that the rocket was motionless while the bolides traced back and forth in different directions. Observing this, a young member of the expedition suggested that the relative motion of the bolides could be used to accelerate or retard the rocket without expending any fuel.

"All we have to do is to hitch a ride," he said.

"A splendid idea," Laplace remarked, "but unfortunately we can't make use of it because we lack the necessary

implements. The rocket would probably withstand the jar and we could survive if submerged in water, but the greenhouse would be destroyed."

The Earth grew smaller and smaller, the day became longer: thanks to the longer day, night set in suddenly, and more and more followed the lines of an ordinary solar eclipse lasting several hours. A day in the rocket was already equal to ten terrestrial days. The Moon alternately expanded and contracted; at its largest it was a most striking spectacle. At one point its maximum size became equal to that of the Earth. The latter's dimensions did not change in the course of the day, i.e., as the rocket circled round it, but it shrank gradually, as the distance increased. In the course of half the rocket's day the Moon expanded considerably, then dwindling rapidly until it became even smaller than as seen from the Earth. The apparent diameters of the Earth and the Moon became equal when the rocket reached a point $^4/_5$ of the distance between them, or 48 terrestrial radii from the Earth. Soon that point was passed.

The cloudless day grew longer and longer. Flowers and fruit flourished in the Sun. During oppositions of the Earth and Moon the latter seemed larger. Lunar attraction exerted a growing influence on the rocket's motion. The velocity would first increase, then be retarded by the pull of the Earth's satellite. The orbit or path of the rocket was distorted, and it could even have hit the Moon, but that did not happen.

Finally, however, the rocket reached the orbit of the Moon, moving in the same direction and with the same velocity as the Moon, but on the other side of the circle, so that they could never meet.

There were no more nights, only eclipses of the Sun, which were as rare as lunar eclipses on Earth. A continuous day set in.

The motors were stopped. The Moon was far away and seemed even smaller than when seen from Earth.

The rocket's orbital period about the Earth was the same as that of the Moon, its synodic period (with respect to the Sun) being about 30 terrestrial days. In its spiralling away from the Earth the rocket more and more infrequently overtook the Moon, until finally it began moving with the same speed as the Moon, which seemed fixed in the sky.

This happened when the rocket was the same distance from the Moon as from the Earth.

The distance between the rocket and the Moon became constant. As the rocket seemed stationary to its inhabitants, so did the Moon and the Earth. Both traced their paths among the stars, but the impression was that the stellar sphere was moving.

38. DOUBTS. SHOULD THEY VISIT THE MOON!

The space between the Earth and the Moon for 360,000 kilometres round the Earth had been thoroughly explored and found to be quite safe and almost free of bolides. People could now begin their transmigration. A telegram to that effect was flashed down to the Earth. This time the mirror had to be larger, and a reflector 10 square metres was used. A telegram from the Earth acknowledged the receipt of the good news.

"Mankind will now embark on a new era of colonisation," Newton informed his weightless audience. "We for our part must discuss our future plans. We have good grounds for satisfaction and confidence: we have carried out our plans, the rocket is coasting round the Earth in the orbit of the Moon, which presents no danger to us and cannot perceptibly affect our motion, we are adequately provided with food. Our position has changed only relative to the Moon and the Earth, remaining the same in relation to the Sun and the stars."

"We can take one of three courses by switching on our motors," Laplace said. "We can land on and explore the

Moon and attempt to determine its importance to the Earth and in general. We can accelerate our ship to a velocity which will take us forever from the Earth and put us in orbit round the Sun. Thus we can explore an expanse about our luminary which is hundreds of millions of times greater than the surface of the Earth. Finally, we can develop a negative velocity, i.e., reduce our speed with relation to the Earth, in which case we shall begin falling earthwards drawn by its gravitational pull. In five days of accelerated fall we shall dash to smithereens against its surface."

"That's the least desirable course," several voices exclaimed.

"A trip round the Sun can also be postponed!"

"Why not try to reach the Moon?" came the suggestions from all sides.

"It is feasible," said Newton. "But we can't take the greenhouse to the Moon with us. When we start retarding our motion on approaching it there will be developed in the rocket and the greenhouse a relative gravity not less than the gravity at the Moon's surface, i.e., minimum one-sixth of the Earth's gravity at ground level. The greenhouse can't withstand even that small gravitational force."

"Consequently," Franklin said, "we'll have to leave the greenhouse here and proceed in the rocket carrying stores of food and oxygen. This means that we shan't be able to stay long on the Moon, especially if we all land together. On the other hand, we can't leave anyone in the greenhouse because a space-suit must not be worn for more than six hours, and even if we could extend this time indefinitely, it would be most tiresome to remain continuously in a space-suit."

"Suppose we dismantle the greenhouse, stow it away in the rocket and then set it up on the Moon? Then we can dismantle it again and fly back," some of the workers suggested.

"This has been discussed," Ivanov remarked, "and it was found impracticable."

"The only thing to do," said Newton, "is for all of us to fly to the Moon for a short period without the greenhouse. We'll gather as much fruit as possible and then reduce functioning of the greenhouse, leaving regulators to supply the plants with moisture, nutritious substances and everything they need for several dozen hours."

The question of visiting the Moon was debated for some time, before a satisfactory solution was finally arrived at. The greenhouse would be equipped with a slowly revolving polyhedral mirror. The light reflected by its facets would be seen several thousand kilometres away.

But let us now leave our weightless travellers and return to the Earth.

39. EVENTS AT HOME

While reaction-propulsion crafts and greenhouse parts were being built, new experiments carried out and new instruments manufactured, the inhabitants of the Earth were dreaming about, arguing over and reading everything that appeared in print about the new trans-atmospheric colonies. Some opposed the idea of colonisation, some were indifferent, but the majority ardently supported the idea. Many books appeared devoted to life outside the Earth. People poured over colourful pictures illustrating life on the future colonies. The children were the first to pounce on those pictures, they were followed by the younger men and girls, and finally the adults. Sceptics predominated among the old folk and women, but the girls were as enthusiastic as the young men.

Lectures were delivered and papers read at meetings, learned societies, and academies all over the world.

People impatiently awaited the first flights. The telegram from our trans-atmospheric travellers that they were well and had explored the space between the Earth and the Moon was received with general satisfaction.

The question of selecting the first colonists was widely debated. Half the population of the world—some 2,000 millions—had volunteered, but in their heart of hearts many thought, "Let someone else go first. I'll follow the lead. There's no haste." Children fancied themselves flying about, cavorting, playing and skimming in air and the boundless ether.

People imagined how nice it would be to be rid of overcast skies and to enjoy the constant sunshine. The inhabitants of northern and cloudy lands were the most anxious.

"You can't get along without nights," the sceptics wagged their heads.

"Darkness is easily made," the optimists countered.

Weak, ailing and old people longed for the Sun even though they were apprehensive of some of the conditions in the new life. They wished for repose, freedom of movement and tropical heat, but they had their doubts about weightlessness. Poor people relished the prospect of breaking away from want and the squalor that inevitably accompanies poverty.

"There's nothing shameful in being naked among other naked people," they said. "Why, some might even take pride in a beautiful body and give themselves airs—without having a penny in their pockets!"

"How much energy it takes to overcome the hostility of beds, homes and clothing! It's all very well for the rich to talk! But the poor and the weak suffer most from vermin, especially in hot countries where the level of culture is low; it is they who find it so hard to combat vermin and insects."

Everyone was impressed by the possibility of controlling the temperature from zero to 150°C.

"This means," they said, "that we can always have 30-35° C at home. In such easy conditions, with the temperature almost equal to that of the body, the organism expends the minimum of energy, making it possible

to be contented with every little food and still put on weights."

Vegetarians were pleased to hear that their diet would consist of fruit and vegetables.

"But there's nothing to prevent us from breeding animals there," contended the lovers of meat.

"Oh, no," the vegetarians argued, "you won't be allowed to."

The discussion spread to the newspapers. It was announced that the higher animals would not be slaughtered in trans-atmospheric colonies. Even on the Earth the consumption of meat was gradually falling because of the increasing variety and quality of fruit and vegetables and because the expansion of world trade had made the finest fruits available to everyone. Moral considerations, natural compassion, and an organic abhorrence of blood had led to a position where only sick people included animal flesh in their food.

Sick and aged people donated huge sums of money to hasten the beginning of the transmigration. Doctors assured them that there were better conditions for recuperation and prolongation of life in outer space: eternal sunlight, a constant, healthy temperature, complete bodily rest, absence of blankets, beds, clothing, no pressure and contact with anything. The slightest effort was sufficient to change the position of the sick patient. Every part of the body was free and accessible, and there was no danger of ever developing bed-sores. Finally, there was the total absence of infecting agents.

"It's immoral to expose the body," the pessimists declared.

"There's nothing to prevent you wearing clothing if you so wish," the exponents of the new way of life countered. "Besides, it will be obligatory to conceal certain parts of the body."

"Men and women almost naked! It's awful!" the moralists exclaimed in horror.

"They'll get used to it," replied the positive advocates. "If they don't, it will surely mean that such people are spiritually unchaste and should be left on the Earth. Not everyone will depart, in any case. Someone will have to remain here. The Earth will continue to require looking after just as before and even more, otherwise it will become a hell. At first we'll send up just a few people, the most physically fit and, what is more important, morally sound. Later on, only the overspill population of the Earth will be resettled."

Everyone was glad that there was no need to do any travelling, no need to overcome gravity, friction, the resistance of water and air, with the exception of the air inside the rockets or the very rarefied air in the greenhouses. The journey could be made without clothing inside the rocket or in a space-suit outside. In both cases people would be racing through the void without ever stopping or feeling the drag of the medium.

"A rocket will be like a gaol," the doubters grumbled.

"Not a gaol but a spacious home with every possible convenience of the kind that even the most powerful people cannot at present enjoy," the supporters replied.

"Furthermore, you can leave the rocket from time to time. All you have to do is get into a space-suit and you are free to move in all *six* directions."

"A space-suit is cumbersome," the grumblers continued. "Your eyes are always behind glasses. It's clothing all over again, but worse and more inconvenient."

"Up there a space-suit will weigh nothing, and in any case it's much more comfortable than the garments of an Eskimo or a Yakut. Space-suits are still far from perfect, of course, but when they are improved you'll be surprised at the result!"

"We'll see! But then, you never have the pleasure of a stroll on foot, everything is so monotonous, and the black sky and the lifeless stars are dreadful. Here I can see the blue sky, the glorious sea, the lovely colours of the air,

hills, valleys and woods. A medley of sounds caresses the ear wherever you go. What can be better than a thunderstorm in spring, the babble of a brook, the murmur of the trees, the pounding of the surf on the beach. . . ."

"That is so," the exponents rejoined. "But how many people have the time and opportunity to enjoy them? On the other hand, in the greenhouses there will be flowers, fragrance and beauty galore, and, in addition, the opportunity to enjoy them. A tired, work-weary person cannot take in the beauties of nature. Enlightenment and association with large numbres of people will be a great recompense for the absence of terrestrial romance. Besides, to some extent, reading books about the Earth and looking at pictures of the Earth will make up for its absence. People will be able to visit the Earth once in a while. But goodness! how disappointed they will be after their carefree life in the skies! The visitor to the Earth will be like an old man hankering after his native parts. His childhood and adolescent memories are so pleasant that his childhood haunts him because of their seeming charm and delight, because childhood friends seem so attractive. . . . Yet when he finally reaches home he finds. . . . Ah me! but every old man knows what he finds and how disheartened he is."

Many people agreed that a world without gravity had its advantages: walls couldn't fall or ceilings cave in, people could not trip up and fall or slip and break their bones; every position was achieved effortlessly, the legs and arms would never grow numb, and freight haulage would cost nothing. All this was known and had been discussed, but it was pointed out that there were many occasions when gravity was essential, for example, when washing or in a lavatory.

"Even if you are right to regard gravity as essential," a physics teacher protested, "there is nothing simpler than to produce it by rotating your dwelling. Rotation up yonder is permanent and costs nothing. Furthermore, its speed

depends on us, we can make it less than on Earth or more, within infinite limits. This is our advantage. Terrestrial gravity is constant, but there it can be of any force from zero upwards. Now about the temperature. Close to the Earth it can't be lowered very much because of the planet's heat radiation. But farther away temperature control can be accomplished within very wide limits. At the distance of the Moon, where our travellers are at this moment, the temperature can be brought down to almost absolute zero, i.e., to 273°C below freezing point. This is of tremendous importance for industry," the teacher went on. "On Earth it is very difficult and expensive to achieve low temperatures. Up there it is virtually possible to get +150°C and —250°C simultaneously. A difference of 400°C! Then take the absence of gases for metal-working. It's impossible to enumerate all the opportunities and indisputable advantages available!

"Due to its spherical shape," the physicist continued, "the succession of days and nights and the absorption of the atmosphere, the Earth receives only about one-eighth of the amount of radiant energy received up there. Clouds and mists further considerably reduce this figure. Then the absence of insects and other pests and the favourable moisture and fertiliser conditions afford fabulous yields of crops. A very small greenhouse can feed one person with hardly any tending. Weeds are destroyed by preheating to a temperature of 100 degrees. And this requires no fuel, and in general fuel is redundant up there."

"You could be a lawyer," someone remarked sarcastically. "Better say what'll happen if by accident all the gas escapes from the greenhouses and dwellings? Everyone'll die."

"Proper care must be taken. If you make a hole in the dykes of Holland the whole country will be flooded!"

"But some loss of gas is inevitable. How will you make up for it?"

"Water seeps through dams, but it is not regarded as a catastrophe."

"And the bolides and asteroids! They supply gases, and water (in solid state), and building material. An asteroid one kilometre in diameter has a mass of about 5,000 million tons and it can supply an enormous population for a long time. There are any amount of these asteroids which escape observation in the finest telescopes, even in favourable circumstances."

"But no one has ever seen them!" several voices exclaimed.

"Hundreds of asteroids 10 metres and more in diameter have been discovered. Our travellers report that they have seen many bolides and even gathered a small collection of celestial rocks. We find many aerolites in museums here on the Earth. The smaller a celestial body, the more of them there are. There are thousands of ten-mile planets. There are probably many more smaller ones, only the low power of our telescopes makes it impossible for us to see them. There is a tremendous amount of interstellar dust, which manifests itself in the shape of shooting stars and which probably settles on the snow of the polar countries."

Unfortunately, we are unable to recount all the arguments of this nature. Often the same things were repeated over and over again and we have given here only the most characteristic arguments.

40. EARTH TO ETHER AND BACK. ESTABLISHING NEW COLONIES

The rockets were built and equipped along the lines already described. Thousands of them left the Earth one after another, roaring and thundering and spitting fire, to the delight of onlooking crowds. First only scientists, technicians, engineers and workers were dispatched, all of them young, energetic and in excellent health, and all of them builders.

On the advice of the scientists, a swarm of these rockets was put into orbit at a distante of 5.5 terrestrial radii, or 33,000 kilometres, from the surface. They circled the planet in just one terrestrial day. Daytime was almost continuous, being interrupted every 24 hours by a brief solar eclipse which could hardly be regarded as night. The Earth was seen at an angle of 16°, i.e., it looked like a huge moon 32 times broader than the Moon seen from the Earth. The latter seemed alternately slightly larger or slightly smaller than usual. Everything else was as described, only on a smaller scale. The rocket's velocity in relation to the Earth was 3 km/sec.

Newcomers to that strange world were first awed, then delighted, but they gradually got used to the situation and engaged in work as described before. They used structural elements to build a number of greenhouses. Later it was decided to adapt them for habitation as well. Accordingly, the gas pressure was brought up to one-fifth of atmospheric. It consisted mainly of oxygen—80 per cent—the other 20 per cent including carbon dioxide, water vapour, etc. The absolute amount of oxygen was only slightly less than on the Earth at sea level. The oxygen, however, was much more stimulating, because it was almost pure and not overburdened, as it is on the Earth, with a lot of useless nitrogen. The pressure was rather low, but all the new settlers had passed the examination to test their ability to stand the reduced pressure. The greenhouse atmosphere had a double advantage: the oxygen was more effective and the walls of the structures were subjected to only one-fifth of atmospheric pressure, making it possible to reduce their weight without detriment to strength. The greenhouses were not exactly identical with the one described. They were designed for living and were built stronger than the ones designed only for plants, and which had a very rarefied atmosphere.

Thousands of rockets shuttled freight between the Earth and outer space. Several of them remained in orbit as

dwellings for the builders, but they could always return to their native Earth at short notice.

The homeward journey was a reverse of the upward path. The sensations and flight conditions were virtually the same, the only difference being that the velocity was reversed as the exhaust was directed against the motion. The speed was gradually reduced until it reached zero at the Earth's surface. For safety reasons it was actually reduced to nil long before landing. The rocket hovered in the air before slowly descending until it softly touched the ground. The landing technique may sound simple, but in practice it required great skill to stop the rocket at the split second when it touched the ground in the desired point. That is why a greater amount of propellants had to be used in landing than in launching a rocket of the same mass. Usually a rocket would land in a big mountain lake not far from the launching site. Then it was towed to the shore and transported back to the launching pad.

The construction crews were rarely relieved because they had to pioneer the building of space colonies, and in addition, the work was very light and clean. Parts were rapidly welded together with great accuracy by focusing sunlight in a parabolic mirror.

The first greenhouse was finished in 20 days. It was a long tube like the one described, but 1,000 metres long and 10 metres across. It was designed for accommodating and feeding 100 persons. There was 100 square metres of longitudinal section of the cylinder, or 100 square metres of surface for each inhabitant continuously subjected to the normal rays of the Sun (except during eclipses). The side facing the Sun was transparent over one-third of the circumference. The reverse side was opaque metal with small portholes. Thanks to an extremely strong, silvery wire reinforcement glass could quite safely withstand the pressure of the inside atmosphere and heavy blows. The nontransparent wall was still stronger. The temperature in the long tube was regulated on the outside and inside, and

could be varied from —200°C to +100°C. This was mainly achieved by altering the radiating capacity of the outer shell. The non-transparent part was black. Over it was a system of burnished shutters. When the shutters covered the black skin, the radiation of heat by two-thirds of the surface stopped almost completely. Sunlight continued to stream into the greenhouse and the temperature could rise to 100°C. When the burnished shutters were retracted, the exposed black metal envelope gave off intense radiated heat into stellar space and the temperature in the greenhouse fell. If the shutters were drawn over the glass to keep the sunlight out the temperature could drop to 200°C below zero. The temperature extremes could be further widened by means of a third, inside shell. If you recall the Dewar flask, in which things keep hot and cold so well, you will understand the principle. The centre of the cylinder, its axis in fact, was occupied by a pipe filled with soil. Passing through it were two smaller pipes which continually supplied air, fertiliser and moisture to the soil. Seeds and seedlings of fruit-bearing plants and vegetables were planted in numerous holes in the soil pipe. A silvery net divided the cylinder longitudinally into two semi-cylindrical compartments. The front, sunlit section was only partially shaded by grapevines and other plants clinging to the windows. This section was open to all, regardless of sex or age. The second half was shaded by dense, lush vegetation. It had few windows through which only the starlit sky, the Moon, and the Earth shining 1,000 times brighter than the Moon, could be seen. Adjoining these windows, i.e., the metal part of the greenhouse, was a row of compartments or separate rooms, 200 in all. One hundred were for families; then came 50 rooms for bachelors and widowers and 50 rooms for unmarried women and widows. Every family occupied not less than two adjoining rooms, one for the husband, the other for the mother and children. Single persons were given a room each, but as half the rooms remained unoccupied, there were usually va-

cant rooms separating the bachelor rooms. Further on was a series of rooms for families, then a series for girls, and finally for youths. There were six long drawing-rooms between the dwelling quarters and a vast hall. Three drawing-rooms faced the family quarters: one for the married men, another for wives and children, the third for mixed gatherings of wives and husbands. The other three drawing-rooms faced the bachelor quarters: two for youths and girls separately and a room in between where they could meet together.

The stainless lateral and longitudinal netting was covered with dense foliage, flowers and ripening fruit. Their fragrance filled both private and public rooms. What could be more beautiful than these rooms, with their walls of blossoming, fruit-bearing verdure! The thin golden shafts of sunlight hardly pierced through the luxuriant foliage.

All rooms except the children's had only one door, which could be locked. The doors of the girls' rooms, for example, opened into the girls' drawing-room, which led to the joint girls' and youths' drawing-room, and finally to the hall where all the inhabitants could assemble. Working implements were mostly stowed away in the drawing-rooms, but if desired they could also be kept in private rooms.

The general assembly hall was designed as follows. If you stood on the green partition, assuming it to be the floor, you would have the Sun directly overhead and it would give no shade. The Sun would have been unbearable but for the plants, which softened its harsh light. From this position you would have a view of the magnificent hall with its vaulted glass roof and green floor. You would be in no danger of getting entangled in the foliage or falling through the floor, as there was no gravity and the firm silvery netting prevented it. The hall was 10 metres wide, 5 metres high and 1,000 metres long. It provided ample space for the 100 inhabitants. If they all entered the hall simultaneously, each had about 400 cubic metres of space.

True, the plants occupied part of it, but not much. The cylinder was some 30 metres in circumference. Thus, the vault occupied 15 metres. The transparent part spanned 10 metres, ending 2.5 metres above the green carpet. There were more rooms than were required. Let us imagine one of them. It is 2.5 metres high, 9 metres long and 5 metres wide. If we took up a position in it with our feet to the Sun, along the line of the sun-rays, we would see overhead a vaulted opaque ceiling with small portholes with rays from the Earth streaming through them, generally obliquely. The light is quite sufficient for reading.

The six drawing-rooms were each 2.5 metres high, 167 metres long, and 10 metres wide. The direction of height, width or length depended on the position of the observer. By making the greenhouse revolve slowly about a lateral axis its position in relation to the Sun was kept constant, because the plane of rotation possesses the property of maintaining a constant aspect. The gravity generated by the rotation was hardly perceptible and had no effect on freedom of movement. The artificial gravity was greatest at the ends of the greenhouse, where the toilets and baths were located, and there it served the useful purpose of keeping the water flowing through the vessels and helping with the natural functions of the body.

Mention should be made of a very important part of the greenhouse: the moisture, or humidity, regulator. Subjected to the steady hot rays of the Sun, the plants transpired large amounts of water and rapidly drained the soil. This should, presumably, have made the greenhouse atmosphere terribly humid. But this was not so. A special humidity-control system was set up to rectify this. Along the shaded external side of the greenhouse there passed a black metal refrigerating pipe. Air was continuously pumped through it, and the vapour condensed. The rate of condensation depended on the temperature of the pipe, which, as explained before, could be lowered to almost —200°C. Of course, there was no need for such a low temperature;

a few degrees of cold was sufficient. After heating, the air in the greenhouse became very dry. The condensed water was driven, by means of a jet of air or by the rotation of the greenhouse, to the ends of the greenhouse, where the toilets and bath-rooms were located. There it was finally purified for washing, after which it was pumped into soil pipes.

One of the effects of the absence of gravity was that there was no air circulation in spite of differences in temperature in the differently shaded parts. The centrifugal force produced air streams, but they were too weak. Ventilators were therefore installed which mixed the air and cleaned it of dust, leaves, fruit and any objects that might be drifting about. Air streams flowing to the cooler could also be used for ventilation.

The builders joined several greenhouses together into the shape of a star or some other shape and made them rotate slightly so that the transparent half of the structures would always face the Sun's rays.

But let us leave our architects to their work of building trans-atmospheric habitations and return to our celestial explorers, travelling in the Moon's orbit at a speed of one kilometre per second. We shall visit the settlers again, when more of them have moved to their new dwellings.

41. FROM LUNAR ORBIT TO THE MOON

We left our scientists in the Moon's orbit at a distance of 360,000 kilometres from the Earth. You will recall that they had decided to visit the Moon. At a new meeting, however, the original flight plan was completely revised. For the sake of fuel economy and so as not to jeopardise the greenhouse, which was their main source of food, it was decided that only two men, travelling in a specially designed rocket, would embark for the Moon. With a crew of two a large, strong, heavy rocket would be unnecessary and the thrust force could be reduced to a fraction.

In addition, a small rocket could be adapted for negotiating the lunar surface and skimming over gorges, mountains, craters and volcanoes. The first was achieved by providing the rocket with wheels driven by accumulated power since, once on the Moon, it would not be possible to count entirely on solar energy; the second was achieved by placing additional exhaust nozzles in such a manner as to counteract the small weight the rocket would have on the Moon. Wings would have been useless, as our natural satellite has practically no atmosphere.

So while down on the Earth far from our scientists new colonies were being arranged, inside the rocket a new lunar vehicle was being designed and built. An engineer by the name of Nordenskjöld passionately wished to fly to the Moon and Ivanov wanted to go with him. The company voted that they should go.

They were given a great send-off and, more important, their supplies and the functioning of their equipment were thoroughly checked. A large group of men in space-suits sallied forth to see the rocket off. It rapidly picked up speed, the send-off party fell back and the rocket disappeared. The men left behind returned to their quarters.

The exhaust gases escaped in the direction of the small rocket's motion, and soon it accelerated to two kilometres per second. The relative gravity was small and there was no need for the lunar travellers to submerge in water. To save time, however, they later increased the exhaust to raise the gravity to terrestrial gravity. How pleasant it was to feel the tension in one's muscles produced by just standing or lifting an arm! At first they turned pale, as the blood drained to their hands and feet. They had grown so unused to gravity and become so pampered by weightlessness, that soon the change in gravity began to annoy them. When the state ended 100 seconds later, they sighed with relief and felt no craving for a return to gravity. On the contrary, they relaxed in the small space of the rocket

as they might have done in a feather bed after a hard day's work. The apparent diameter of the Moon increased perceptibly. The relative velocity was one kilometre a second, but it gradually increased due to the Moon's pull. This force, however, could not increase the velocity to more than two kilometres a second. The initial distance to the Moon, measured along the orbit, was 1,200,000 kilometres. In seven days it was almost halved. Now, if they did not retard the rocket, they would be taken away from the Moon. The velocity was reduced by firing the exhausts against the rocket's motion, and their path curved down till it entered the Moon's orbit. The motors were stopped and the relative gravity again disappeared. Five days later the Moon was at a distance of 200,000 kilometres and seemed twice as large as when seen from the Earth. As they drew closer the face of the Moon broadened, visually confirming their approach. On several previous occasions they had already been closer to the Moon than now, so its apparent increase in size did not interest them greatly. Still, knowing that within a few hours they would reach its surface, they inevitably cast apprehensive glances at it. For all they knew, something might go wrong and they would be dashed to death against its surface.

"Isn't it time to decelerate?" the Swede asked anxiously, his eyes riveted to the Earth's satellite.

"No," said Ivanov. "We must wait until the Moon's attraction increases the relative speed of the rocket to two kilometres a second."

There was still much time. They nibbled at some food and from time to time persuaded one another to take food as they nervously looked about them. The Sun was as blinding as ever, the huge Earth shone forth, displaying its pattern of continents, seas and lakes. All round them was the black sky studded with lifeless stars and occasional planets. They kept their eyes on the Moon, the apparent size of which soon equalled that of the Earth, only later to surpass it in size and then to dwarf it.

Another day passed, and the Moon began to expand rapidly, growing in size by the minute.

"How awful," the Swede exclaimed involuntarily, gazing with awe at the enormously bloated Moon. Seas, craters, gorges and strange bright stripes and dots stood out with clarity. The map of the Moon lay before them in a striking, transfigured, enchanted, living form. They saw valleys and mountains never in any telescope seen from the Earth. The travellers were approaching the Moon from "the side" and could see half of its reverse side.

"Isn't it time to brake the rocket?" the Swede asked, unable to hide his agitation.

"Yes, in a few moments."

At a distance of two thousand kilometres the Moon presented an angle of 50°, and covered one-seventh of the celestial sphere. It was a terrifying sight indeed to behold. Its diameter was 100 times larger than usual.

They switched on the braking rockets. Once again they felt their weight, though it was much less than on the Earth. They sat on the floor; beneath them was the huge Moon looking like an overturned embroidered parasol, forming part of the heavenly sphere.

"We'll be on the Moon in half an hour," said Ivanov.

The gleaming parasol beneath them expanded till it covered almost half the sky. Their pulses quickened in anxious anticipation. Mountains, valleys, cliffs and craters appeared as close and clear as a terrestrial landscape. Several kilometres separated the travellers from their destination. The retro-exhaust increased and the rocket slowed down.

"We are motionless," said the Russian, who had been observing the Moon in a goniometer.

The exhaust was reversed, the rocket gathered speed, and the direction of the relative gravity shifted so that the Moon immediately seemed to be above their heads. Two or three kilometres from them were the hills and dales of the Moon. With the relative gravity directed away from the

Moon, it was strange to see its surface hanging overhead like a ceiling.

The illusion was so great that Nordenskjöld continued to mutter. "How are we going to walk on that ceiling? What shall we hold on to?"

"Don't worry," Ivanov reassured him, "everything is all right."

The rocket was approaching the Moon, only two and a half kilometres away, at a speed of 100 metres per second. The thrust force became equal to the Moon's gravitational pull. The rocket began coasting with a constant velocity of about 100 metres per second. The relative gravity vanished again and the travellers could observe the Moon from different aspects, depending on the position of their bodies. In 20 seconds they were only 500 metres away and braked the rocket once more. The gravitational force shifted and the Moon appeared beneath them. In another 10 seconds the explorers touched the Moon with scarcely a bump. The manoeuvre was carried out as follows. When the rocket was almost grazing the soil and had all but come to a standstill, it was tilted over until it landed on its four wheels like a cat falling on its feet. It rolled on for several score metres and came to a standstill.

42. OVER THE HILLS AND DALES OF THE MOON

Dead silence enveloped the motionless rocket. The two men seemed stunned, as if they had just come out of a deep sleep or come to after fainting. Finally, the Russian rose to his feet, stretched himself, and said:

"We're on the Moon. Gravity here is one-sixth of that on the Earth. It's quite perceptible," and he flourished his arms and shuffled his feet.

Gravity no longer seemed strange to them, for they had experienced it several times during their trip. There was a difference, however, between true gravity due to the attraction of a mass and relative gravity. Relative gravity

appeared when the rocket was accelerated or uniformly decelerated, and it depended on the thrust force. Since this force could never be absolutely constant in magnitude and direction, relative gravity fluctuated, creating slight jolts of the kind experienced on a fairly good road. Relative gravity induced by rotation was free of jolts or fluctuations. For objects and people moving not too rapidly, inside a rotating body, relative gravity was not different from gravitational pull, except for the slight dizziness experienced by some people. The majority, however, felt no unpleasant sensations, especially if the radius of rotation was huge. When one moved quickly, the gravity produced by centrifugal force displayed itself in very interesting phenomena, which will be described on a more suitable occasion. The travellers' sensations on the Moon reminded them of their native planet. They were like some unexpectedly familiar fragrance, conjuring up childhood memories.

"It's cold," the Swede remarked.

"Yes, it is chilly."

Night peered in at the windows. The ground could hardly be seen. The heavenly sphere embraced them from without, pitch-black and dusted with countless unblinking stars. The Earth was nowhere in sight. They felt helpless, sad, even frightened. A dark jagged mass looked dimly on the horizon. The sky above it was powdered with silvery star dust.

"You know," Ivanov said, "we're on the reverse side of the Moon, the side people have never seen and where the Earth never shines."

"But the Sun does shine here," the Swede said, "and we'll wait until it rises."

"Naturally. And then we'll see what no one on Earth has ever seen."

"When will the Sun rise?" the Swede asked. "We'll freeze if this night lasts for several hours."

"The Sun will soon appear," the Russian replied. "The horizon over there seems to be getting brighter already. Dawn must be approaching."

"There is no dawn here," the Swede remarked. "The Moon has no atmosphere, consequently there can be no dawn."

"There may be a very rarefied atmosphere, but it is not that which produces the light of dawn. The hills illumined by the Sun cast reflected light on the still dark summits, which then reflect it further, etc. This produces the lunar dawn, which is very weak and unlike dawn on the Earth. . . ."

"See how the light of dawn has grown brighter, while we have been talking," the Swede said, peering out of the window. "But it's terribly cold. Let's switch on the electric heater."

"Go on then, press the button," the Russian said.

"We're not so badly off," he continued. "Because of the void all round us and the polished double shell of the rocket, the cold penetrates to us very slowly. The rocket's envelope reflects heat rays wonderfully, preventing them from escaping either into outer space or into the lunar soil."

"Half a tick!" the Swede exclaimed. "What's that gleaming over there in the east?"

"Direct rays from the Sun have lit up a mountain top," the Russian replied calmly.

"Which means the Sun will rise soon. . . ."

"Oh, no! You've forgotten that the lunar day is 30 times longer than a day on the Earth and here the Sun rises correspondingly more slowly."

"Quite right. I had clean forgotten: if we were on the Moon's equator, the rising of the Sun would last exactly 60 minutes."

"Correct," Ivanov said, "since at the Earth's equator it takes two minutes for the Sun to rise."

It grew warmer from the heater, and their spirits rose accordingly. Another mountain top flashed into existence, followed at once by two more. It had already become light enough to discern one or two things. When they had landed

they had not switched on the light, although they had tried switching it on, only to find later the surrounding darkness even more foreboding. So they had switched it off. They could then at least observe the familiar patterns of the constellations: the Dipper, Orion with the bright Sirius, the Milky Way spanning the heavens. This cheered them immensely. Now, since they had long ago grown accustomed to the black sky, they could at least see something.

An hour slipped by unnoticed in the pleasure of watching the rising Sun kindling the mountain tops. They had been without the Sun for only two hours, but its loss had been such a torture that they hailed the first rays with shouts of delight. Their eyes were dazzled. The Sun gradually climbed over the horizon, but it was not the "red Sun" of terrestrial dawns. It was a bright, bluish Sun, twice as powerful as when directly overhead on the Earth's equator. Towering hills, valleys, cliffs and rocks hove into sight. One side of the rocket faced the Sun, but thanks to its polished surface it did not become too hot.

"We'll be warm now without the heater," the Russian remarked. "Please turn that lever to cover the side facing the Sun with a black surface."

"Ready!" the Swede reported.

Soon it grew terribly hot.

"I say," the Swede said, "didn't I switch the heater off? Why, it is off. . . ."

"I'm suffocating," said Ivanov, and he pushed back a lever so that the side facing the Sun became striped, with sooty black and silvery bars. It grew colder. They moved the lever back and forth till they achieved the desired temperature of about 30°C.

"Now it's just right," the Swede said with satisfaction. "And what are we going to do now?"

"We can go out and take a walk to stretch our limbs," Ivanov suggested. "By the way, a stroll here will be an unusual experience. We can explore the neighbourhood and

then ride around the Moon in the rocket, which can travel like a coach on wheels. We can skim over gorges, craters and mountains by using the motor thrust to counteract the small lunar gravity."

"Splendid," the Swede agreed. "But what about air? There seems to be no atmosphere here and the soil must have grown terribly cold during the long night."

"The temperature of the soil must be about —250°C, as the Sun hasn't warmed it yet," the Russian observed. "But that's of no consequence. It was worse when we had nothing under our feet and nothing to protect us from radiation. Cold as it is, the ground gives off much more heat than interstellar space, which virtually sucks warmth from everything in it."

"But how can we walk on the cold ground?"

"We'll get into our space-suits, take a supply of oxygen and put on special shoes with soles which hardly conduct heat. The hot Sun will warm us just as well as the rocket did. Here is the striped clothing that will absorb as much heat from the Sun as is necessary, even a little more."

"Suppose we wait until the Sun has warmed the soil," the Swede suggested.

"We'll lose too much time: the soil is too cold to warm up very quickly."

They decided to leave the rocket, so they put on their space-suits and special shoes. The Swede entered the air-lock first, closed the inside door, left through the outside one and slammed it tightly shut. The Russian followed suit. They alighted on the Moon's soil. Alongside them was the rocket standing on wheels. Not being designed for travelling through air, it was built in the shape of an ellipsoid which was only three times as long as its height, and it looked like a funny old-fashioned coach.

Everything around them sparkled and shone in the rays of the Sun. High mountains loomed in the distance. They stood on the fairly smooth floor of one of the so-called "seas". The Sun warmed them and they felt no coldness

from the soil. They looked about thoughtfully for several minutes. But they soon had to shift about, as their suits grew too hot on the sunny side and too cold on the shady one.

The sight around them was strange and beautiful, their bodies felt light, the Sun was bright and warm. Their spirits rose rapidly. The Russian rubbed his hands, hugged himself and experienced a tremor of sheer joy. The Swede pranced about delightedly and soared four metres up. The jump took him three seconds. The Russian ran ahead, making huge leaps three metres high and 12 metres long. Each leap increased his stride till he was jumping over clefts and fissures 24 or more metres wide. They picked up rocks so light that they seemed to be wooden or hollow. A 96-kilogram granite boulder weighed only 16 kilograms. When they threw up a stone, it flew six times higher than when thrown on the Earth, and took so long to fall back that our friends grew tired of waiting, for its flight lasted six times longer and it travelled six times farther than on the Earth.

Very slowly the Sun climbed higher and higher. The shadows stood out very sharply defined, though not absolutely black because the surrounding sunlit hills and mountains reflected light on them. It was impossible to remain in the shade for more than a few minutes, for without sunlight it was bitterly cold. Only the human body radiated heat and very soon the cold drove one to a sunny spot. The two men played leap-frog with the greatest ease and they could lift one another without the slightest effort. They could turn several somersaults during one leap, and even when they failed to land on their feet they hit the ground very softly. They gambolled and raced about and turned cartwheels like children, paying no attention to anything else. But soon they grew tired of romping about. The Russian stooped and scraped the ground with his foot. It was covered with a thin layer of dust below which was something hard like granite. In other places the dust layer

was thicker, and deposits were of considerable thickness. Some were soft, others had caked into a harder crust, and others yet were quite hard. A special thermometer encased in a metal rod showed the temperature inside a dust layer to be —250°C. At the surface the deposit was already warmed by the Sun's rays. There were outcrops of bare granite. The ground was strewn with rocks, which seemed very light, and big granite boulders lay scattered about in the distance. The hills and mountains looming beyond them seemed very close and small. There were many fissures, especially in the bare granite, most of them narrow and scarcely noticeable, others several metres wide. There was an occasional crevasse. The dust was pock-marked with holes, large and small. Our friends ran about in different directions to see the sights. They easily cleared large boulders and fairly wide gorges. Every now and again they stopped to share their impressions. They could not talk directly, because of the extremely rarefied atmosphere, so they had to put their helmets together or stretch a steel wire from one to the other. The ground did not transmit their voices as the soles of their shoes were poor sound transmitters.

"I've always wondered," the Swede said, "both here, and out in space, why it is we seem to see a 'firmament'. There's no air here, so why the illusion of a firmament, even a black one? Flammarion rejects the idea of a firmament on the Moon."

"This illusion is easily explained," said Ivanov. "The eye is unable to discriminate between large distances. That is why the stars, Sun and Moon all seem equally far away, i.e., attached to the inside surface of a sphere with ourselves at the centre. This gives the illusion of a semi-spherical firmament. On the Earth it looks blue and flattened at the top because the denser air at the horizon obscures stars and terrestrial objects. We are accustomed to thinking that objects darkened by the air are more distant. That is why on the Earth the firmament seems flattened. In the

ether and here there is no air, the stars and hills are not darkened and the sky seems round. That, by the way, is why the stars and hills seem so close and toy-like. Something of the same, although to a smaller extent, is observed on high terrestrial mountains, where everything also seems closer and smaller than in the valleys.

When the men looked towards the Sun they saw fewer stars because their pupils contracted in the sunlight and in the reflected light of the sunlit mountain slopes. From the depressions, where there were few sunlit features, from the shade, and especially from the hollows and crevasses, they could see as many stars as at night.

The Sun rose very slowly, climbing at the rate of one diameter an hour. It needed 180 hours to reach noon. The shadows were very long. It was dangerous to go too far from the rocket. The deep craters, into which the Sun's rays could not penetrate, were dark and cold, and our friends were afraid of losing too much heat in them.

They made a tentative descent into one gorge. The edges stood out in the Sun, but the bottom was lost in darkness. They found a sloping entrance and began to climb down. When darkness enveloped them and countless specks of stars glimmered overhead they switched on a powerful electric torch. The walls flashed into being. Here and there they were studded with what looked like hieroglyphic characters. The walls were warm, and at a depth of 5-10 metres the thermometer showed about 20°C. The Russian fingered the granite rock and found that it closely resembled terrestrial graphic granite, or Jew Stone, which contains very little mica. The temperature hardly changed as they went deeper and it felt quite warm. At a depth of more than 100 metres the walls grew smoother and took on a lustrous hue. The Swede scratched an especially shiny patch.

"I say," he exclaimed, "this is metal! See how it shines!"

"Owing to the scarcity of oxygen only the top layers of the lunar crust have become oxidised," the Russian

responded. "This produced granites at the surface, leaving light metals and alloys lower down. This crevasse was probably formed after the Moon lost, or rather absorbed, its own atmosphere."

They chipped off samples of rock and metal at various depths and after reaching a depth of 1,000 metres returned to the surface. Both the descent and ascent were an extremely simple business. The 64-kilogram Swede felt as though he weighed a mere 12 kilograms, while the lighter Russian weighed only 11 kilograms. Similarly, their 16 kilograms of minerals and metals weighed only about 3 kilograms. There was no moisture or humidity in the gorge, though it mattered little to them as they were breathing the synthetic air mixture carried on their backs.

It was time for a rest and food, and soon our companions with their precious loads reached the refuge of the rocket. After eating and resting they again put on their space-suits and went out the same way as before.

In conditions of terrestrial gravity motion, though fatiguing, is freer than in unconfined ethereal space and it can be altered at will. On the Moon freedom of movement is further facilitated by absence of fatigue, thanks to the low gravity. Only the space-suits inconvenienced our travellers slightly. What a new world lay before them! What a wealth of astonishing discoveries! And how natural that their high spirits were due not only to the relief of treading on hard ground, but also to the pride of being the first explorers of the Moon, to their thirst for knowledge and simple curiosity.

The Sun rose some 20 degrees, the shadows grew shorter and the soil warmer. Slopes perpendicular to the Sun's rays became quite warm. The men ran towards a nearby hillock. They climbed to the top but were forced to halt before an abyss. They stood at the brink of an extinct volcano. It was still dark very far down, and they could hardly see the bottom. In the centre of the black disk there glowed one lone spot, probably a mountain peak lit

up by the Sun. They did not venture down the crater, preferring to make their way around it. At some points the ground sloped gently outwards and inwards; in other places it sloped steeply. Avalanches had heaped piles of rock and rubble at the foot of the hills. In general the inside slopes of the crater were steeper. Here and there they saw stately pillars of basalt. On their way back they collected samples of porphyries, basalts, trachytes, lavas, syenites, hornblendes, and feldspars.

"It seems to me that something is moving in and out of the cracks," the Russian said.

"I've noticed it, too," the Swede remarked.

They looked more carefully at cracks and holes. Sure enough, ever more frequently something would fleet by, a shadow would run and disappear hastily. The men tried to approach the apparitions, but they disappeared before they reached them. Finally the Swede raised his field-glass to the flat visor of his helmet.

"It's alive!" he cried. "There it is running across the plain... now it's hidden in a hole...."

"Let me have a look," Ivanov asked, impatiently snatching the binocular from his hands. "Why, they're green, with something like twigs on their backs. They look like moving shrubs. We've got to catch one of them."

They were unsuccessful, however, for the nimble creatures disappeared as soon as the men approached. More and more of them appeared as the soil grew warmer. Some sat still, warming themselves in the Sun, others scampered across clearings between burrows. They were of different shapes, sizes and colours. Most of them were green, but there were also red, yellow, orange, and black ones, as well as some multicoloured. Their bodies were covered with spots which sparkled like glass. The smaller creatures were digging in the dust and seemed to be swallowing it. The larger ones chased the smaller ones, worried them and dragged them to their burrows where they probably devoured them.

"Theoretically the temperature on the Moon should vary between —250°C and +150°C," Ivanov said. "Obviously, in such harsh conditions, to say nothing of the lack of moisture and any adequate atmosphere, no plant can grow in the lunar soil."

"That is so," the Swede agreed, "but you have in mind terrestrial forms of vegetation. If a plant could acquire some degree of intelligence, or at least instinct and the ability to move, it could live on the Moon. We can't reject offhand the possibility of plants developing such capacities, especially if we take into account the well-known facts, for example, the existence of insectivorous plants on the Earth. There is nothing to prevent these travelling plants from sheltering from the cold in deep crevasses where the temperature is quite normal, i.e., about 22°C at the equator and lower in the upper latitudes. When it gets very hot, i.e., towards the end of the long day, they could again seek refuge in the deep lunar fissures."

"I haven't seen a single ordinary plant with roots," Ivanov remarked. "The terrific temperature extremes here would have killed any stationary flora. Even in deep gorges plants would perish from the shortage of sunlight."

"Neither have I noticed any plants like those on the Earth," the Swede remarked. "These travelling plants resemble some marine species containing green chlorophyll. Many of them, particularly the very smallest, microscopic ones, owe their existence to the Sun alone, while larger ones live on sunlight and by preying on the smaller ones. The processes here are the same as in terrestrial oceans, without the water and the substances dissolved in it.

"Here living creatures consume dust containing oxygen, carbon, hydrogen and many other elements necessary for life. The Sun transforms the elements into water and the various complex bodies which constitute the living world."

"The outer skins of their bodies are practically impervious to gas, which prevents them from drying up," the

Russian observed. "They derive energy from sunlight by devouring other creatures or, more frequently, in both ways. Thanks to this energy they move about and even think a little."

"Under the influence of the Sun's rays," the Swede added, "the chlorophyll of their bodies breaks carbonates and other simple compounds into carbon, oxygen, etc., which combine to form the complex tissues of the body. These, in turn, decompose during muscular and mental functioning into simple compounds which are generally excreted. These creatures, however, do not excrete them but with the aid of sunlight reprocess them in special appendages to their bodies. Thus, once formed, these creatures have no need of food, i.e., no need to consume external substances, organic or mineral.

"We've no time to discuss this subject, however, and even less time for experiments. Let's travel round the Moon and rejoin our companions before we exhaust our supplies. When we return the greenhouse will supply us in abundance. After all, we can't eat these creatures; they may be poisonous, and we don't know how to catch them."

"I think," the Russian said, "that we should not ride inside the rocket but on its upper platform, with the special railing, seats and light adjustable awning."

"It will be more interesting to travel eastwards towards the Sun, across the unknown half of the Moon. Firstly, we'll come to steadily warmer ground and, accordingly, to more active life; secondly, the long lunar day will pass more quickly and we'll be able to observe some interesting phenomena at sunset."

"Right you are," the Russian agreed. "So let's have a rest and then set out. We'll gather some more minerals for our collection."

Several hours later found them reclining in seats on the rocket's upper platform and racing towards the Sun almost along the planet's equator at a speed of 10 to 100 kilometres an hour, depending on the state of the road.

They kept to valleys and plateaux, skirting the towering peaks and even the small craters and hills. They were forced to follow a tortuous route, and the Sun kept shifting to the right, left and rear. Their space-suits shielded them reliably from the lethal effects of the Sun's rays. The wheels revolved as they steered their way to the south and then northwards. They negotiated small gorges without a hitch, took running jumps over the larger ones, and skimmed over gorges several hundred metres (and even several kilometres) wide, clutching the railing for dear life, but not forgetting to steer the vehicle. When they spotted a gorge in the distance they switched on the motors, which cancelled out their slight weight and their vehicle raced with tenfold speed over crevasses, gorges, small craters and hills. But they rarely indulged in this sort of thing, for they were economising on fuel.

Their rapid progress to the east made the Sun seem to quicken its pace and rise more rapidly. At a speed of 15 kilometres an hour, the Sun seemed to double its pace across the sky, i. e., in an hour it appeared to pass through a whole degree instead of half a degree. At 105 kilometres an hour, the Sun seemed to pass through 4 degrees in an hour. This speed made it possible to travel round half the equator in 45 hours.

"I say," the Swede remarked, "the Sun is setting in the east!"

"That's because we've turned back to skirt that mountain and aren't moving westwards."

"It turns out that we can control the motion of the Sun, make it set or rise, move faster or slower or stand stock still, or make it rise in the west and set in the east," the Swede remarked as his eyes swept the luxuriant landscape.

"Quite right," the Russian replied. "The Moon is small and the speed of its equatorial points is correspondingly small: less than 4 metres a second, or about 15 kilometres an hour. If we travel at that speed along the Moon's equator in the opposite direction, our rotation will be can-

celled out and the Sun will seem to stand still forever. At night this would keep us always in the dark, in the daytime we should remain continuously in the sunshine. By altering our speed we can make the Sun move now faster now slower, or rise and set unnaturally or in some unusual manner."

They had to stop every three or four hours and get inside the rocket for food, rest and to check their spacesuits. After a rest they emerged in the highest of spirits and ran about collecting rock samples. So far they had found no precious metals. They usually made a halt when something special attracted their attention. They saw several avalanches of flashing, sparkling rock slide down the slopes of a steep, towering 10-kilometre mountain range, spanning the horizon behind them. Huge rocks, boulders and whole mountain-sides tumbled down the vast height. There being no atmosphere, the rocks hurtled down unimpeded at a terrific speed and smashed to smithereens at the bottom. The debris of recent avalanches not yet covered with dust sparkled in the Sun with all the colours of the rainbow. The sunlight playing in the translucent crystals produced an interesting spectacle. The reason for the landslides was quite obvious although the Moon has no dense atmosphere or abundance of water to cause rock erosion by their movement and freezing like on the Earth. The chief reason here for the landslides was the tremendous extremes of temperature during the day and the night which reached 400°C. These extremes gradually split the originally solid rock. The cracks grew deeper and wider and one day, if the slope was steep enough, the rock slid down. This was followed by more avalanches due to the same cause. The rubble heaped up at the foot of the hills soon prevented further landslides. Furthermore, as the gradient of the hillside decreased, the fractured rocks remained in place. Many mountains on the Moon had already reached that state and no longer crumbled or lost height. But many craters continued to disintegrate. On several occasions our

companions felt distinct tremors due to huge avalanches, several of which they even observed. The sound reached them considerably muffled by its passage through the ground, as the extremely thin atmosphere scarcely transmitted it at all.

The awning of the rocket hid the bluish Sun but did not prevent them seeing the black semi-spherical sky with its familiar pattern of constellations. Only the light reflected from the hillsides reduced the number of visible stars. Deathly silence reigned, except for the noise of the motors which reached them through the walls of the rocket and their chairs. Not a cloud or tree or blade of grass was to be seen. Only the green lunar animal-plants, scared by the movement and noise of the rocket, scampered out of the way. The absence of trees, green meadows, lakes and rivers, snows and the blue sky was discouraging.

"Look there," the Russian called out. "What's that moving towards us? It looks like a green cloud. Over there, in the direction of the big cliff."

"I see it! It's probably a flock of lunar animals."

The Swede raised the binoculars to his eyes and saw a flock of creatures leaping like kangaroos in hasty flight towards the west. Ivanov took the field-glass but the creatures, scared by the rocket, swerved suddenly and disappeared behind the nearest hill. Our travellers saw the creatures several times again. They came to the conclusion that not all the denizens of the Moon sought refuge from the cold in gorges and clefts. The larger and stronger species enjoyed eternal sunlight and the warmth of the soil by keeping pace with the luminary, spending their lives in constant migration and preying on weaker creatures. To keep pace with the Sun they had to cover an average of 14 kilometres of ground an hour moving westwards. With the feeble attraction of the Moon, this continuous, moderate motion was quite possible and not at all difficult to achieve.

During their halts the two men climbed over the debris strewn at the foot of steep, sometimes overhanging, granite

cliffs, collecting whatever they most fancied. They found transparent quartzes in the shape of huge chunks of rock crystal; reddish orthoclase and dark hornblende were scattered about abundantly; occasionally they found zircons, garnets and tourmalines. Unbroken pillars of greenstones, reddish porphyries, and magnificent basalts of various colours stood all round. Our companions foraged at the foot of the pillars, going into raptures from time to time at the sight of the beautiful stones. They filled their hampers with red rubies, transparent orange-coloured jacinths, dark melanites, blood-red pyropes, violet almandines, sapphires, emeralds and amethysts. They also found diamonds of different colours, though rather small specimens. Many samples of rock crystal were pearly, pink and other colours. There were many hydrates (water compounds) of quartz such as chalcedony, semitransparent jasper and opal, but most of all there were flints. Among the chalcedonies there sparkled red cornelian, green bloodstone with a sprinkling of red spots, and agates.

Once they spotted a white, snow-like mass in the distance. When they approached it they saw among the fragments of gneiss and the mica schists a whole field of diamonds, some of them as large as a fist.

"Here are riches which exceed the combined wealth of all people!" the Russian exclaimed. His companion, however, did not hear him, for their helmets were not in contact.

The men pounced eagerly on the treasure. They had to throw away many fine stones to make room for the most interesting diamond specimens. With their baskets full they hurried joyously to the rocket and sealed themselves in.

There were many diamonds; they had also collected some gold dust. But their stores of food were running low and they had to leave the Moon without studying it as thoroughly as they would have liked to. While resting, they ate bananas, nuts and pineapples, and quenched their thirst with water-melons and grape juice. They cheerfully sorted

their riches, poured aquamarines, emeralds and diamonds from one hand to the other, from time to time glancing out of the windows.

"All these riches," the Russian said, "probably with the sole exception of gold, of which there is not much here, are now only a mineralogical collection. When the Moon becomes accessible to everyone, its gems and diamonds will lose all their value even on the Earth."

"Look, there's a bright light to the left!" the Swede exclaimed.

The Russian turned and saw a sheaf of sparks rise from one of the lunar hillocks. Several seconds later, there was a loud crash, which probably reached the rocket through the granite soil, and which caused the walls and air inside to vibrate.

"That was a bolide," the Swede remarked. "It hit the granite surface of the hills full force without losing any of its tremendous velocity through the friction of the air. That's why it flared up like a miniature sun."

"The fireworks were probably produced by a lump of iron which melted, let off steam and broke into pieces," Ivanov said.

This guess was confirmed when they left the rocket and found the bolide. The place of impact abounded in hot fragments of iron fused with rock. The smaller fragments had already cooled and the men gathered several for their collection. The pieces differed in no way from the familiar terrestrial aerolites.

43. FAREWELL, MOON! RECEDING FROM THE MOON

The temperature continued to rise and it was becoming tiresome regulating it. Here was a further inducement to abandoning the Moon.

They selected a smooth slope with a gradient of 10 to 20 degrees. They placed the rocket there, locked themselves in and switched on the motors.

"Farewell, Moon!" the Swede exclaimed, looking out of a porthole.

They glided along the slope, took off and raced through the ether round the Moon. Higher and higher they climbed, accelerating gradually until they reached a velocity of 1,600 metres a second. The motors were cut off and they went into orbit round the Moon at a distance of 250 kilometres from its surface. Travelling at that speed, they could circle the Moon in two and a half hours. At first they flew over unknown terrain with strange mountains and craters, but soon they came to the known side of the Moon. They saw it as a terrestrial observer would see it through a telescope with a thousandfold magnification. Their view of the known face of the Moon was much better than could be provided by the most perfect reflector, for there was no atmosphere or lenses to distort the image. The Moon was enormous. It occupied one-third of the celestial sphere (120°) and seemed concave, like a bowl, with the rocket at the very centre. In some respects it reminded them of the Earth at a distance of 1,000 kilometres, only the Moon was lifeless and dreary, having no atmosphere, water, clouds, vegetation or snows. The rocket passed over the Sea of Tranquillity and the mountain ranges; they saw the craters Plinius and Posidonius, the depression Lacus Somniorum and more mountains; the craters Bessel, Menelaus and Manilius passed below, followed by more craters and mountains without end; the Caucasus slipped by and the crater Calippus beyond them. Beneath them were endless plateaux and the plains known as seas, but containing less water than the Sahara desert. They were fringed with craters and mountain ridges. The terrain was littered with rubble and volcanic debris. Craters of all sizes pockmarked the face of the Moon and fissures snaked in all directions. It was an impressive and instructive scene, but there was no time to waste, for their stores had fallen low and they had a long journey ahead before entering the Moon's orbit and joining their comrades. As they flew over

the known side of the Moon, they had a simultaneous view of the Earth. It was like a Moon in the sky, but its apparent diameter was 2°, i.e., four times larger than the Sun. The appearance of the Earth from near by has already been described. From afar it was much the same, only smaller.

They circled the Moon for several hours before switching on the rocket motors. When they accelerated to about 2.5 km/sec and entered the orbit round the Earth they stopped the blast. The Moon grew smaller and smaller, its apparent size shrinking from 100° to 40°, 20°, 10°, 5°, until it became the size of the Sun. Long before that, their velocity had dropped too much and, time being precious, they accelerated the rocket. According to their estimate, they should have sighted the big rocket with the greenhouse already. In vain they scanned the sky with field glasses. They had all but abandoned hope, when suddenly they spotted a flash in the rocket's polyhedral mirror, which reflected sunlight across thousands of kilometres. Joyfully they saw it flicker in the void. There could be no doubt that some two thousand kilometres away their companions were amusing themselves. They steered towards the flashing star, and three hours later sighted the big rocket and greenhouse.

44. THE BIG ROCKET AGAIN. MESSAGE TO THE EARTH ABOUT THE MOON

The reunion was a joyous one. The two men were greeted with a barrage of questions, but they declared flatly that they needed a rest and a good meal after their experiences. Several hours later Ivanov and Nordenskjöld gave a detailed report of their adventures and demonstrated their collection of minerals and gems. The listeners were especially delighted when they saw the huge glittering diamonds.

A message on the following lines about their adventures on the Moon was telegraphed to the Earth: "We are well

and happy and circling the Earth in the Moon's orbit on the diametrically opposite side. Two of us landed on the Moon, travelled across it and made a collection of lunar rock specimens. Owing to shortage of vital supplies they had to abandon the Moon without making the thorough study desired. Nevertheless we have obtained the following information: the invisible hemisphere of the Moon differs in no substantial way from the visible side seen and studied by terrestrial astronomers. Hardly a trace of atmosphere and water exists. The firmament is semi-spherical, not flattened, black, with countless non-twinkling stars. Day and night are 30 times longer than on the Earth, therefore at night the temperature drops to minus 250°C while during the day it reaches plus 100-150°C. No ordinary, stationary and rooted plants were found. There is a fairly varied living world. It is a combination of the vegetable and animal kingdoms and can be treated either as mobile plants or animals with chlorophyll in their skins and capable of feeding on inorganic food like most terrestrial plants. The Moon is covered with innumerable cracks ranging in size from fissures to gorges. The temperature in the gorges is constant, reaching +25°C in equatorial areas. The lunar animal-plants use them as a refuge from heat and cold. They are quick and nimble as they must escape being caught and devoured by larger and stronger creatures. Of the latter, not all live in burrows, and some travel in the wake of the Sun's rays, thereby constantly enjoying the temperature most favourable to them. We were unable to collect any specimens of living organisms. We saw no structures, such as buildings, machines or bridges, which would suggest the existence of intelligent beings and we presumed therefore that no lunar creatures have developed to the level of Man. The Sun moves at one-thirtieth of the speed observed from the Earth. It is possible by running to keep up with its movement, to make it move in any direction, to change day into night, and sunrise into sunset, etc. In general, all the astronomical data are confirmed. For

example, the Earth is visible only from the hemisphere of the Moon visible from the Earth. It has the same appearance as the Moon, but its diameter is four times larger. It always stands motionless at the horizon, a little above it or in the zenith. At the same time, its position fluctuates slightly in the course of a month. These fluctuations are hardly noticeable, except at the horizon. The Earth changes its position when one moves about on the Moon, even when walking very slowly. Thus it can also be made to move in any direction. A vehicle or person must travel at about 4 metres per second, or 14 kilometres an hour, to make the Sun change its position. This and much greater speeds are possible not only for vehicles but for pedestrians as well, as gravity on the Moon is only one-sixth of that on the Earth and there is no air resistance. Neither are there any winds, of course. The Earth is never visible from the unseen side of the Moon. The nights there are lovely with countless numbers of multicoloured stars. With the Earth in the sky, the lunar night is so light that one can read print. It is also beautiful, though some time after sunset, when the temperature becomes bearable. Stars can be observed alongside of the Sun and the Earth, though in varying numbers; from the bottom of craters, depressions and gorges as many stars as at night can be observed. The Moon is entirely unsuitable for living purposes, in view of the absence of water and air, but chiefly because of the tremendous difference (400°C) between the temperature in the daytime and that at night. For this reason alone it would be impossible to grow any crops. The inorganic world is rich in minerals, gems, and unoxidised light metals and their alloys, to be found deep in the gorges. Mountains, elevations and plains consist of granites, syenites, basalts, trachytes, and of the volcanic rocks generally known on the Earth. In some places we found a sprinkling of alluvial deposits which seemed to consist of settled dust. Few heavy or precious metals were found. On the other hand,

diamonds were in such abundance as to cause apprehension on Earth that prices would drop sharply. Beautiful women may look forward to adorning themselves with gems to their heart's delight, when a steady traffic has been established between the Earth and the Moon. No volcanic activity was observed. Avalanches and landslides are frequent. Bolides strike the surface with tremendous displays of fireworks and blinding flash of light. Because there is no mitigating influence of water and air the contrasts in temperature are extreme. The depressions and pits which are always in shadow are terribly cold. It is probably even colder in such places in the north and south polar areas. Thick layers of solidified water and air may possibly have accumulated there, but there are no factual data in support of this. An effect of dawn is produced by the many times reflected light from the mountain peaks which shines over the terrain. For the same reason shadows are not quite as pitch-black and also not as grey as on the Earth. In some places, most of them low-lying, thick alluvial deposits were found which were probably formed when the surface of the Moon had not yet cooled completely, when the temperature was uniform, and the water and gases had not yet become liquefied and absorbed by the soil, and therefore flowed and wore down the granite as on the Earth."

45. TERRESTRIAL AFFAIRS

The telegram was received on the Earth with jubilation. Many were disappointed to hear that the Moon was unfit for habitation, but the jewellers were alarmed and began to plot against all reaction-propelled vehicles. Impecunious lasses slyly eyed their more fortunate wealthy rivals. But on the whole, this first visit to another planet aroused great enthusiasm, courage and hope. In any case the Moon could be of use to mankind!

The news about the diamonds and gems created a sensation among the dandies of the world. The price of jewellery

dropped heavily. Many rich people invested large sums in the manufacture of reaction-propelled vehicles in anticipation of a boom in diamonds and other lunar commodities.

* * *

Meanwhile at a distance of 5.5 terrestrial radii, or 34,000 kilometres from the Earth's surface, new colonies were expanding and people settling in. The greenhouse dwellings described before became populated with happy men, women and children. People lived comfortable, prosperous family lives.

46. THE EXODUS AND LIFE IN THE ETHEREAL COLONIES

The finest types of people were selected for the colonies: people who were sociable, gentle, resourceful, industrious, physically enduring, not too old and, preferably, unmarried. But they outnumbered the requirements so they were assembled in terrestrial communities where they lived, interested themselves in one another and continued to select people for the space colonies from among themselves. Even so there were still more people than the accommodation available out in space, and a third selection became necessary. The men and women finally selected were ideal in every respect, regular angels in flesh and blood. However these "angels" were subjected to rigorous tests before being allowed to leave for outer space. They were placed in an atmosphere containing the same amount of oxygen as at sea level but with the nitrogen removed. Then the amount of oxygen was reduced by half, bringing it to the concentration equal to that on top of a five-kilometre mountain. Those who fainted, felt discomfort or weakness or lost their appetites were not accepted. It was essential that they should feel well on a diet of fruit and vegetables. Thus at the very first selection many "angels" were rejected. There were cases when accidents occurred. Once almost

all the air was pumped out by mistake. This was noticed only five minutes later. Everyone had fainted. Most people regained consciousness, but three of them died. The survivors were readily granted permission to embark, for if a similar accident ever happened to them in the colonies because of some breakdown in a greenhouse, they would indeed be sure to survive. This was a great advantage. It was hoped that, by training, it would be possible to develop in people the ability to survive after short spells in a pure vacuum. They would then be almost completely safe in the trans-atmospheric colonies.

The selectees were sent off in very crowded rockets, but as the whole journey lasted only 10 to 15 minutes it was not at all tiresome. The journey was too brief to require any description, particularly as we have already described one such flight. The passengers had hardly enough time to look round them and take stock of their surroundings before their experienced guides hauled them out of water and conducted them with the already described precautions to a greenhouse.

At first the newcomers found themselves in a common hall 1,000 metres long, 10 metres across, and 5 metres high. They were impressed by the size of the room, the abundance of greenery and the golden sunbeams piercing through. There was some enchantment about the whole spectacle. The hall seemed endless. At first newcomers noticed only the foliage, the light, and the transparent vaulted ceiling. They felt lost, though the guides did everything to give them encouragement. Looking about, they saw dark specks fluttering in the distance like flies or butterflies. A closer look revealed that these were their companions who had arrived earlier, and they thereupon exchanged joyful greetings and warm embraces. The old-timers had small wings rather like fins down the sides of their bodies, which they moved with their legs, imparting translatory motion in a gaseous medium. They were easily folded and removed like clothing.

People moved about like fish or birds. There was no gravity and wings were not essential if one made swimming motions or pushed off from fixed objects. Wings, however, were more convenient, as they made it possible to move quickly and gracefully with the slightest effort.

"Mamma, what are they, angels or devils?" the children cried. "They won't send us to hell, will they? You know, I did tell a lie. I did eat the pastry, only please don't tell them. . . ."

The children were wide-eyed in astonishment, some of them cried and tried to run away—but they ony floundered helplessly. Little by little the parents, themselves excited enough, soothed their children, while the "angels" procured wings and helped newcomers to adjust them. The latter soon learned to propel themselves in any direction. It was all really quite simple, though at first there were many cries of dismay and annoyance.

"Oh, Mummy, I'm flying in the wrong direction and I can't turn!"

But the "angels" would guide the child back and teach it to use its wings.

"I'm afraid, Masha, it's not so easy to learn to fly! I'm all tangled up in these plants and can't extricate myself."

This one, too, was helped.

"Alexander, what am I to do? I can't turn to the right."

Alexander, who had already been put through his paces and could fly about dextrously, hurried to his wife's assistance.

"Look at me, Mummy, see how I'm flying!" little Olya squealed. "See, I can fly to the windows, to the wall and back."

The people had not yet become hungry and everyone was in a delightful humour, though they felt a little bit lost. The transformation had been so sudden, that most people felt they were dreaming.

"How warm it is!" the children cried. "Before it was only warm like this in hot summers."

Everyone had cast off their travelling clothes in favour of light shorts. The temperature was about $+30°C$.

One family promenaded down the vast hall. Other families drifted towards them. The sunlight streaming through the foliage cast whimsical patterns on the fluttering groups. The latest arrivals were left to themselves to look around and become accustomed to their new life and new duties.

What were the colonists engaged in? Could they do nothing but gambol, eat and sleep? They had every opportunity of doing just that, but in actual fact things were otherwise.

So far the population of each greenhouse was not large, a mere 400. Yet it could provide food and shelter for up to a thousand. The space habitations were built by the people from the Earth and in part actually down on the Earth. Builders from the Earth arrived to assemble the greenhouses and fit them out with everything necessary for plant-growing. The new settlers owed their comfort to the Earth, to the effort of their brothers. That, as it were, was their reward for the good qualities they possessed which had earned for them the right to be selected for what was now their native planet.

Could the colonists undertake immediately to build such a greenhouse dwelling for others or themselves? Not yet, because the settlement of outer space had only just begun. The population in space was still sparse and it was impossible to build the factories and workshops required for complex output. What is more, they lacked the necessary building materials. Delivery from the Earth was very costly. It would have been easier to supply them from the Moon, but that would also be inexpedient. The explorers whom we left in the Moon's orbit hoped to be able to give assistance in the form of inexhaustible supply of the necessary raw materials from space itself. Then would be the time for activities on a more varied scale, when there would be no longer any need to rely shamefacedly on help from the Earth. And yet, what was so shamefaced about

it? The child relies on its parents, the infant takes its life-blood from the mother! Who should reproach the weak! The time would come when they would work to the best of their ability.

The settlers, however, were sufficiently occupied with keeping their spacious homes in order, studying themselves and teaching others, engaging in scientific research, developing themselves mentally, physically and spiritually. But it is impossible to manage without some form of social organisation. They had their own elected leadership. Each group of boys, girls, bachelors, married folk, old men and old women, put forward its own elected representative. In all there had to be 8 representatives, but since it would be wearying for one person to handle affairs without intermission, each group elected 3 or 4 persons who took turns in the performance of their duties. These 20-30 delegates chose three or four from their midst to be responsible for the overall leadership; the latter also took turns in office. Elections were called whenever the population found it necessary to replace poor administrators or those who had been in office for too long. The elected representatives were issued special badges so that everyone could recognise his or her deputy. The badges were in the shape of a dried fruit, a flower, a sprig of immortelle, or something else of the kind. Here there would be a group of youths flying past like a swarm of bees following their leader with a large flower badge; there would come a charming flock of children with their elder; a group of girls wafted by with their elected leader ahead of them wearing an attractive wreath; there would be the old men and women with their representatives; the married men, the wives and the infants.

The other deputies kept together in a separate group until they would be called upon to exercise their authority in one way or another. The old folk had old leaders, since young people are not so readily capable of understanding their emotions, mode of life, behaviour and requirements.

Similarly, women were governed by women, as a women's world is almost beyond the comprehension of the mind of the man. For the same reason children had their own representatives, for adults often forget their own childhood weaknesses and requirements and old women—their maidenhood and motherhood.

A committee of representatives handled all the affairs appertaining to the population as a whole, regardless of sex or age. Actually these duties were relegated to one acting representative, either a man or a woman. Thus, all matters were dealt with speedily and efficiently. If many members of a population group found fault with the actions of their deputy, he was replaced. The deputy was the mouthpiece of the average cross-section of public opinion, which is why he was elected. Similarly, in every population group, in the girls' group, for instance, the deputy expressed the common will, by virtue of which she could issue orders and partial laws for just as long as she enjoyed the confidence of the others. Inevitably there were dissenters, but the cohesion of each group and the whole population required such an organisation. Being in constant contact, the colonists could size up one another, which was very important. Thanks to this they were able to elect those candidates who best qualified for office and for the work. Marriages and divorces were made effective by a deputy from the whole population. Disputes inside each group were settled by the representatives of the group in question. Differences and quarrels among the members of the different groups were settled by the common representative for the entire colony. But in actual practice there were no reasons for squabbles or arguments. Work assignments were also issued by the various representatives. For instance, married women received instructions from their deputy. The main duties in a colony were: 1) to look after the temperature in different parts of the greenhouse. The temperature varied according to the purpose for which the particular premises were used. Thus, in the rooms for new-born babies the

temperature was close to that of the human body, in those for the old people it was lower, in rooms for youths, lower still; 2) to look after the humidity of the air; for this there were special instruments, as already described; 3) to look after the pumps, delivering water and nutritious liquids and gases to the soil; 4) to look after the toilets; 5) to look after the plants; 6) to look after the composition and pressure of the atmosphere; 7) to look after the intactness and condition of the greenhouse skin and see that it was air-tight.

The temperature of the greenhouse skin was constant and nothing could really cause cracking and gas escape. Escaping gas would condense into a mist and be immediately noticed. In addition, escaping gas would close an electric circuit, and the number and location of the damaged place was automatically indicated. The worker on duty quickly located the trouble and placed an emergency plaster on the crack, after which it could be sealed permanently.

Assignments for work were distributed according to ability, desire and physical fitness. Another duty was to keep the greenhouse clean. Leaves, twigs and fruit fell from the plants, and particles of earth sometimes broke away from the soil. All this floated about in the air until the slight centrifugal force accumulated it all at each end of the greenhouse where the toilets were located. Here it was converted into fertilisers. All human and vegetable waste products were dissolved in large quantities of water, which was pumped through the soil pipes. There the water was taken up by the soil and plant roots and given off into the atmosphere by the leaves, adding humidity to the air. The latter was directed through the outside cooling pipes where the moisture condensed into a form of dew, which collected into streams of pure, rain-like water which flowed to the toilets, bath-rooms, drinking tanks, etc.

People wishing to do so could learn reading, writing, arts and crafts and study the sciences. Anyone could teach who

possessed the knowledge, desire and ability and could find the pupils. Instructors were freed from other duties by order of the representative. The system of study depended on the disposition and desire of the teacher and the pupils. While there were still few colonies, arts and crafts were of no great importance and preference was given to science. The general curriculum included geometry, mechanics, physics and chemistry, the study of outer space and the Universe, biology, including the past, present and predictable future of living creatures. Study was given, finally, to sociology and philosophy, and numerous problems so far unsolved. All the sciences were based throughout on mathematical data.

47. UNION OF COLONIES

New colonies developed in rapid succession, and in several years there were very many of them. Communication between them was by means of corridors with air-tight doors. This was a precautionary measure against the possibility of gas escaping from several sections at once if one greenhouse became damaged or destroyed by a bolide. The link-up of several greenhouses reduced the escape of gas and made life in the colonies richer and more pleasurable, since the inhabitants of one greenhouse could visit the colonists in any of the others. The connecting corridors were provided with air-locks, though actually one could pass through them as easily as going from one room to another and there was no need actually to evacuate the air-locks. The doors could have been left open, but they were firmly closed as a precautionary measure.

Several hundred colonies constituted a new type of higher unit. Each colony elected several of its finest members who, taking turns, governed their population. Part of the elected deputies from each colony were delegated to the highest greenhouse where, together with other delegates, they exercised authority in the manner already described.

But there everything was on a more perfect, strict and principled moral plane.

These delegates, after working together, went back to manage the lower colonies, while other deputies took their place. Thus all the delegates took turns in the management of affairs and in the sociological study of each colony.

We have said nothing of diseases or deaths in the colonies. The reason is that no diseases had developed and the colonies were still too new for death with its scythe to have reaped its harvest. There was only one case of mild insanity. One of the settlers imagined himself dead and in "the other" world. No one could dissuade him of this and he became more and more illogical. The leader decided that the only hope of recovery was for him to return home. Soon there were rumours that he had recovered, but had chosen to remain on the Earth.

Let us now leave our colonies to multiply, organise, thrive, progress and expand, and return to the scientists we left travelling in the Moon's orbit.

48. THE TRAVELLERS IN THE MOON'S ORBIT. THE FIRST CONFERENCE

Several times our travellers circled the Earth in the wake of the Moon before deciding what to do next.

"The space between the Earth and the Moon which we have found suitable for settlement," Newton began, opening the conference, "has one major drawback: a shortage of materials for construction and other public needs."

"The delivery of materials from the Earth is far too expensive," Laplace confirmed.

"Materials could be delivered from the Moon," observed Franklin. "The cost would be 22 times cheaper. But Ivanov and Nordenskjöld tell us that the Moon is unsuitable for habitation and work."

"One way out would be to transfer the colonies to the region of the minor planets, between the orbits of Mars

and Jupiter," Newton said. "There is only one thing I am doubtful about: the temperature in the area is rather low. The maximum temperature with a black surface and in the most favourable conditions at the distance of Mars would be about +83°C. Mars is one and a half times as far from the Sun as the Earth is. This is not so bad. Even at double the distance from the Sun the temperature is +27°C. But at the distance of Jupiter it drops to —80°C, and at the mean distance between Mars and Jupiter it is in the neighbourhood of —30°C."

"It could be raised by means of mirrors," Ivanov observed.

"That applies to us in our travels, but not to the colonies, where the much simpler solutions should be found. Our ingenuity, of course, would save us from the cold even at the distance of Saturn. . . ."

"Thus," Franklin reiterated, "the most convenient place for settlement is in the belt close to Mars. There, at a distance twice as far as the Earth from the Sun, the highest temperature for them would be +27°C."

"Wouldn't it be better to build settlements between the Earth and Mars, or even closer to the Sun, between the Earth and Venus?" Laplace asked.

"Either variant would be suitable," said Newton, "if only we could be sure to find matter there in the shape of large bolides or asteroids several hundred metres in diameter."

"One huge asteroid has already been discovered between the Earth and Mars," Ivanov remarked.

"That is Eros," said Newton. "True, the eccentricity of its orbit carries it periodically beyond Mars. It could be made use of, but it's too large. But generally speaking no body less than 10 kilometres in diameter can be detected in the planetoid belt, even using the finest telescopes and the most favourable conditions on the Earth. Thus, even if there are a million asteroids less than 10 kilometres in diameter, they can't be seen.

"And yet," he continued, "they should exist. When you walk in a field, which stones do you see more of, large or small? Small, of course, and the smaller they are the more there are of them. The same should be true of the Universe. Consider, there are only 8 major planets, not counting their satellites. But there are 700 minor planets, or asteroids, and countless bolides and aerolites, to judge by the abundance of shooting stars. This means that we may expect the solar system to have much more than 700 little planets with diameters of less than 10 kilometres. The fact that we can't see them doesn't mean that they don't exist. If bolides didn't pierce our atmosphere, we'd never see them, just as we wouldn't have known of the larger asteroids, had there been no telescopes and sensitive photographic plates."

"We can therefore hope to encounter many small planets nearer than, or farther from, the Earth's orbit," said Laplace.

"And so, gentlemen," Newton concluded, "we shall first direct our celestial path towards the Earth's orbit."

The meeting fully approved his suggestion.

49. THE SECOND CONFERENCE

The second conference discussed the forthcoming trip.

"We are almost free of the Earth's gravitational attraction," Newton said, "which here is 3,600 times less than at the Earth's surface. We are travelling round the Earth at a speed of about one kilometre a second. If we increase this velocity to 1.5 kilometres a second we shall recede from the Earth for ever."

"At the same time we shall still have the same velocity as the Earth rotating round the Sun," Laplace remarked. "We acquired that velocity from the Earth when we were still on it and couldn't have lost it. Thanks to it, we shan't fall on our luminary but will revolve about it like the Earth."

"In other words," said Ivanov, "we need an additional velocity of only half a kilometre per second for our rocket and greenhouse. That is a mere trifle and still our fuel expenditure will be almost negligible."

"Then, in order not to meet the Earth moving along the same orbit, we shall resume the combustion and then, depending on the Earth's direction, shall either spiral away from the Sun or approach it along some curve or other, which will depend solely on us," Franklin observed.

"In this case, too," said Newton, "the fuel expenditure will be very small. But should we travel towards the Sun or away from it?"

"It seems to me," said Ivanov, "that it would be better to travel away from the Sun. The temperature here is high enough and we can raise it to 150°C even without the help of mirrors. In addition, on our way to Eros, Mars and the planetoids we'll encounter lots of little planets with diameters less than 10 kilometres."

The motion was carried and the following photo-telegram was flashed to Earth: "We are well. We plan to travel first along the ecliptic and then away from the Sun in the hope of finding sufficient material for building colonies between the orbits of Earth and Mars. Regards to Galileo, Helmholtz and our other comrades in the Himalayan Castle. Newton." They received a reply telegram wishing them good luck.

50. ROUND THE SUN, BEYOND THE EARTH'S ORBIT

The very smallest blast was used. The attraction of the Moon could be neglected, all the more so as its mass is only one-eightieth of the Earth's mass. Relative gravity set in, but it was so small as to be hardly noticeable. The apparent size of the Earth and Moon, however, decreased perceptibly. Ten days later the angular diameter of the Earth and the Moon had decreased by one-half.

"Our present velocity," said Ivanov, "will carry us completely out of the gravitational attraction of the Earth and its satellite."

The Earth waned rapidly and soon looked more like a bright star than a planet. The Earth and the Moon phases could no longer be observed without a telescope. The phases were identical: if the Earth was in the crescent phase, so was the Moon. The blast propelled the rocket in the direction of its true motion about the Sun. Gradually they left the ecliptic, or the Earth's path. The Earth became no brighter than Venus, with a faint little star, the Moon, close to it.

The only perceptible change in the situation of our travellers was the gradual, apparent shrinking of the two big moons, i.e., the Earth and the Moon, into stars and the slight diminution in the Sun's diameter.

The temperature fell correspondingly, though very slowly and imperceptibly. By increasing the black surface of the rocket facing the Sun the temperature was deliberately kept at the higher necessary level. This dispelled any doubts the travellers might have as to the real possibility of changing the temperature in any direction and within extremely wide limits. As we know, even near Mars it could be raised to +83°C. The greenhouse submissively followed in their wake and provided them with everything they needed. There was nothing to damp their high spirits. They ate, slept and worked with the same serenity as on the Earth. Once in a while, they donned their space-suits and sallied out of the rocket into the ether. The sky continued to be as black as ink. On one side shone the Sun, on the other gleamed a multitude of lifeless, multi-coloured stars. The patterns of the constellations remained the same. The Milky Way continued to divide the celestial sphere into two halves, there were many, many stars and much less mist. The wandering stars, i.e., the planets were visible as before. Large asteroids could be seen without a telescope and stood out because of their apparent motion among the

"fixed" stars. There were no more "moonlit" nights, of course. The thrust force propelled the rocket in the same direction as the Moon and therefore should have accelerated its motion; actually though, the reverse was true and the motion was retarded, but the rocket continued to recede from the Sun. It was like the movement of a sleigh uphill when the speed decreases even though the horse continues to draw it.

51. ON A STRANGE PLANET

They searched with their telescopes for bolides and asteroids or watched the sky for them looking through the portholes. They had been travelling for more than nine months and the monotony had tired them considerably when one day Franklin spotted a vast bulk quite close to them and almost motionless. It was obviously a planetoid moving in the same direction about the Sun.

As the rocket was propelled by the blast the planetoid soon began to slip back. The motors were turned off, then reversed, and they approached the asteroid. The travellers crowded round the portholes, their eyes glued to the vast bulk. Its visible dimensions grew until it occupied almost half the sky. In shape it was very irregular, elongated and rugged. Here and there it sparkled in the rays of the Sun. Everyone was filled with curiosity.

Finally they switched on the retro-rockets in order to slow down and avoid bumping into the planetoid. They came to a standstill and had to switch on the exhaust nozzles again and then switch them off. Several tens of metres separated them and they were hardly moving in relation to the planetoid.

"Enough!" Newton exclaimed. "Let someone moor the rocket to the planetoid."

Ivanov, who wanted to be first, was already in his spacesuit. He immediately departed, trailing after him a light chain attached to the rocket. He approached the planetoid

cautiously, bumping gently against it. There was nothing to attach the chain to, only solid granite and metals. Ivanov decided to use a powerful magnet as soon as he found any pieces of iron. This, however, proved unnecessary: the force of gravity gradually pulled the rocket to the planet. To keep it from hitting against the planetoid, as even the slightest jar might damage the greenhouse, they switched on the exhaust at the very moment of impact. Rocket and greenhouse bobbed slightly against the little world and finally settled down on it and became motionless. The whole population of the rocket flew out, in their space-suits of course, as there was not the slightest trace of any atmosphere.

One could stand or lie or sit on the little planet the same as one does on the Earth, but the gravity was so low that the slightest careless motion sent a person bouncing several scores of feet upwards.

Laplace found a little stone on the planetoid, tied it to a thread and made it swing like a pendulum. But goodness, how slowly it moved! It required a deal of patience slowly to count its oscillations and calculate the time. Nevertheless Laplace carried out the experiment and found that a pendulum one metre long performed one oscillation in 80 seconds.

"We can conclude from this," Franklin said, "that the force of gravity of this planetoid, at the point where we are now, is 6,000 times less than terrestrial gravity. In the first second of free fall a body will here travel just under one millimetre. Like all of you, I weigh 1/6,000th of my terrestrial weight, or about 13 grams!"

The horizon was very rugged. It would be difficult to find anything like it, even in the most fantastic mountain ranges on the Earth. The planetoid was a huge rough, rugged fragment. Beneath their feet were masses of rock impregnated with metallic alloys and pure metals, some of them dark like old iron, others shiny like silver or nickel, some yellow like brass or calcium, others reddish like copper or gold. Various features caught the eye, but they were

compelled to walk very slowly: the slightest impatient or hurried movement sent one high up into space, and one would experience during the descent the whole gamut of emotions, fearing never to return. Those who had little portable propelling motors switched them on, though there was no actual need, and hastened back to the planetoid. Not everyone had them, however, and these would soar up for 10 and more minutes, returning often as long as half an hour. What frustration for those who longed to explore the planetoid! Sometimes they leaped 250 metres away—sufficient for anyone to get lost. Those who had never before found themselves in such conditions found it difficult to become acclimatised. Later they found a fairly simple way of moving about at a speed of 4 kilometres an hour. For this it was necessary to push off horizontally from stones or vertical projections. But too strong a push would bring the danger of flying off the planet for good and becoming a lost soul in the boundless spaces of the Solar System. When this happened it was necessary to resort to the portable motor or to rely on being saved by those who had them.

By this simple method our travellers flew round the entire planetoid and found many pure metals and alloys. The sparkling areas they had noticed from afar turned out to be heaps of gold, silver and nickel. The planet had a thousand times more precious metals than the amount possessed by all the people on the Earth.

Owing to the strange shape of the little planet, its gravity and its direction varied in different places.

Everyone was delighted and astonished at the sight of the treasures. They displayed this by antics and gestures, but the expressions on their faces were almost hidden. They could talk only by getting close to each other and bringing their helmets together; but their curiosity had taken them off in different directions. They took many photographs, made collections of minerals and materials, collected the necessary data for determining the size and

mass of the asteroid, and returned, enriched but not over-burdened, to the rocket. In truth, it would be hard to become overburdened, for a mass of 600 tons weighed only 100 terrestrial kilograms.

52. BACK IN THE ROCKET. THE FLIGHT TO MARS

The motors were switched on again and the rocket sped away from the Sun, exploring the space between the Earth and Mars. The strange planetoid they had just left behind rapidly disappeared from sight, though to them it seemed as if it was the planetoid that was moving away. The scientists, however, continued to study it with great interest. They analysed and examined the rocks, metals and alloys. The gold, silver and platinum were almost pure, with slight additions of other metals. They estimated that the mean diameter of the planetoid was 900 metres. Small wonder that earth-bound astronomers knew nothing about it. It was impossible to spot such a tiny mass at that distance. Even the satellites of Mars, ten times larger in diameter and 100 times greater in area, were only discovered with great difficulty. The volume of the planetoid was about 360 million cubic metres. Its mass could not be determined very accurately, but judging by the abundance of heavy metals even at the surface, it could not be less than 7,200 million tons, assuming the mean density of the planet to be 10. The planetoid rotated slowly.

"It contains enough material to build well-appointed greenhouse dwellings for the whole of mankind," Ivanov said.

"There would be only about one ton per person," Newton objected. "That is not enough."

"If the need arises more heavenly bodies of the kind can be found to supplement the supply," Laplace observed. "We haven't even explored the space up to Mars, and we may well encounter thousands of these miniature worlds on our way."

"Very possibly," Newton agreed.

This proved to be the case, and as they spiraled away from the Sun they encountered asteroids almost every month. Some were larger than the one described, but most were smaller. They left most of them unexplored, but whenever they visited one they almost invariably found heavy and precious metals.

"I find this strange," Nordenskjöld observed. "So little gold and platinum is found on the Earth yet here there is enough to pave the streets."

"Yes, it is surprising," Newton agreed. "Yet according to at least one hypothesis it is easily explained. These comparatively small bulks may well be only parts or fragments of large planets. Being fragments, some of them may contain only the internal and others the superficial elements of a whole planet. The innermost parts of a planet are bound to consist of the heavier elements, such as gold, platinum, iridium and their alloys. This is just what we observe on the discovered planetoids. You will have noticed that we found no heavy metals on some of them, which indicates that they were once part of the outer crust of some larger planet."

"Such a hypothesis was put forward by Olbers to explain the existence of numerous asteroids between the orbits of Mars and Jupiter," Laplace said. "If we can judge by our own discoveries, this probably applies also to the origin of the celestial bodies between the Earth and Mars."

"But what could cause a major planet to break up into several minor ones?" one of the listeners asked.

"There are many possible explanations," said Ivanov. "Chemical processes inside the planet might have produced gases the expansion of which blew up the planet like a bomb, or there may have been a collision between planets, or it may have been due to the steadily increasing centrifugal force resulting from the contraction of a revolving planet."

"Acting alone this force could at most cause the sepa-

ration of satellites or rings, but not such a catastrophe as these fragments suggest," Newton said.

"You are probably right," said the Russian. "A variety of known and unknown causes may have operated," he added after a pause.

"From your words we may draw some interesting conclusions," Franklin remarked. "First of all, our Earth may well be torn to pieces some day. Secondly, the inner parts of our planet should also abound in precious metals."

"Neither possibility can be rejected," several voices commented.

"Well, and if that is so," said Ivanov, "it would be a good idea for the human race to move to other worlds without awaiting such a calamity. A suitable place would be these ethereal deserts which contain all the materials necessary for the safe accommodation here of man."

53. PASSING THROUGH GAS RINGS

Each circuit round the Sun took more than a year, and each year they discovered new worlds. Several times they encountered gas rings, very transparent, tenuous and hardly noticeable, but several kilometres thick. They appeared first as a thin misty strip tapering towards the ends. When the rocket entered the gas ring they heard a strange noise and the temperature definitely increased. The rocket's speed did not differ much from that of the rings, but it passed through them in its movement away from the Sun and soon left them behind. Many rings remained unobserved, like many of the planetoids. They collected some gases from one of the rings, condensed them with the aid of pumps and analysed them. They contained oxygen, nitrogen, carbon compounds, traces of hydrogen and other gases.

"This is wonderful," said Ivanov after the first discovery. "It would be a good idea to place the colonies in a ring of this kind: there would be gases on hand, and in addition, in the event of gas escaping from a rocket, it would remain

in the surrounding atmosphere from which it could be retrieved. This discovery shows that the expansion of gases is not unlimited, as follows from Boyle's Law, and that there is something that restricts it."

"This is not a new conclusion," Laplace observed. "The same has been observed in our own terrestrial atmosphere."

"On the Earth the unlimited expansion of gas is restricted by the attraction of the Earth and the molecular theory," Franklin began.

"And here there is the attraction of the gas ring itself, and maybe something else," said Newton.

"But what?" Franklin exclaimed impatiently. "The attraction of the ring itself is insufficient."

"I don't know," said Newton. "It may be that gases are distributed throughout the Solar System, though in very small quantities. Mendeleyev thought so, incidentally."

54. APPROACHING MARS

Several years passed and Mars was already not far off. The space between the two neighbouring orbits was explored so thoroughly that they were in a position to report the results of their work to the Earth. But this would have required a flat mirror some 100 metres in diameter, the building of which would prove to be a difficult undertaking. It would be simplest to return to the Earth or to send a telegram from the Moon's orbit or from some spot lying even closer.

Near Mars one revolution of the rocket round the Sun took almost two years. The travellers suffered from an accumulation of boredom and nostalgia. When the time came to return to Earth they would, of course, not follow the spiral route. A short route would bring them home in four months. Mars was already 10 million kilometres distant and looked like a miniature Moon 4 minutes across, or 1/7th of the diameter of the Moon as is seen from the Earth. With a telescope they could clearly see its "canals"

and "seas" containing no one knew what, its hills and valleys and the polar "ice" and "snow".

"We shan't go any closer to Mars," said Newton. "To land on the planet would be a dangerous undertaking. We are all tired and, what's more, we have to report our important discoveries to the Earth as soon as possible."

Some objected, others were delighted at the prospect of soon returning home.

"Mars won't run away from us," Ivanov remarked. "We'll reach it in the course of a later expedition."

55. CAN PLANETS BE VISITED!

They had a great deal of free time. The scientists discussed travel plans, but even more they discussed the Earth, its inhabitants and terrestrial affairs in general, which they now viewed most favourably. We, however, would find it more interesting to hear the scientists' views about space travel and conditions of life in other worlds. Here is what they had to say on the subject.

"We landed perfectly safely on the Moon, and find life splendid here where we are almost the same distance from the Sun as Mars! It is warm as before, the fruits do not ripen so fast, but we are adequately supplied. If we were to run short of food there is nothing to prevent our building two or three additional greenhouses," a very young and enthusiastic member of the expedition declared.

"There are difficulties," Newton began, addressing the assemblage. "It will take much brainwork and physical effort on the Earth to overcome them. Let us see what prevents us from landing on planets immediately, apart from our own fatigue and a universal desire to return to our native planet."

The audience fell silent and settled down to listen attentively.

"Let us begin with temperature," Newton continued. "Imagine a soot-black plate perpendicular to the Sun's

rays. It absorbs almost all the rays falling on it. The reverse side should not lose any heat. This can be achieved by covering it, for instance, with polished silver. In ethereal space a plate of this kind will lose heat in proportion to the fourth power of its absolute temperature. This is the law of Stefan and Wien from which we shall proceed in our further arguments. We can check its truth from the following considerations. The experimentally determined constants of this law make it possible for us to solve many interesting problems. Here are some of my own computations. The temperature of parts of the Sun's surface is about 6500°C. That is the normal temperature; the absolute scale begins at 273°C below zero. According to one hypothesis, absolute zero begins with the complete absence of heat in a body. The temperature of our black plate, at the distance of the Earth, may reach +152°C. This is the maximum temperature that can be obtained on the Earth, the Moon, and bodies in space at the same distance from the Sun as our planet. This is also the maximum temperature of the greenhouses and rockets of the colonies near the Earth. It is sufficient to roast meat. I shall not speak about other methods of increasing this temperature, as, for example, with the help of mirrors. Here is the maximum temperature in degrees centigrade for the different distances from the Sun, taking the distance of the Earth as unity:

Distance to Sun	Temp. °C.	Distance to Sun	Temp. °C.
1	+152	Infinity	—273
2	+27	1/2	+322
3	—27	1/3	+450
4	—61	1/4	+577
5	—83	1/9	+1002
9	—131	1/16	+1427
16	—167	1/25	+1852
25	—188	1/36	+2277
36	—202	0	+6427

"It will be observed from this table that the upper limit for space travel is twice the distance to the Sun, i.e., about 150 million kilometres from the Earth's orbit, or 175 million kilometres from Mars' orbit to Jupiter."

"But why can't flat, cylindrical or spherical mirrors be used to raise the temperature in the rocket and greenhouse?" Laplace objected.

"They can," Newton answered, "especially here, where there is no relative gravity and mirrors can be made very thin. But on planets we'd encounter difficulties."

"There are other ways of increasing the temperature in greenhouses, say by making windows which would freely let in the light and highly refractable rays in general while retaining dark heat rays with a low refractability."

"Precisely, dear Franklin," Newton said. "The Sun's rays will enter the greenhouse, change there into dark ones and remain inside, thereby raising the temperature much higher than our calculations show. But as yet I have no exact data about the degree to which the temperature could be raised in this way. For research and information in this field we shall have to rely on the Earth, leaving it aside for the time being."

"Any way," concluded Ivanov, "with the help of mirrors or other devices, it may prove possible in time to travel beyond Mars to Jupiter and maybe even farther."

"I've nothing to say against that," said Newton. "But allow me to draw your attention to the table showing the maximum temperatures for the various planets."

Planet	Distance to Sun	Temp. °C.
Mercury	0.39	+407
Venus	0.72	+227
Earth	1.00	+153
Mars	1.53	+ 83
Jupiter	5.20	— 83
Saturn	9.54	—134
Uranus	19.18	—176
Neptune	30.05	—195

"It will be observed that the maximum temperature on the interior planets is excessively high, yet technically favourable for a travelling rocket."

"Technically?" one of the listeners asked. "But isn't it much too high?"

"Don't forget," Newton said, "that the table gives the highest temperature for ideal conditions which are hardly attainable in actual practice. For the Earth this is +153°. Imagine the same plate set normally to the rays, with the reverse side polished as before, but the front side, instead of being covered witth soot-black, having a surface capable of reflecting and dispersing the light rays falling on it. The temperature will be lower, below zero and even as low as —273°, i.e., absolute zero, if it reflects all the Sun's rays falling on it and the reverse side is covered with soot-black and radiates all the heat into the ether. This conclusion holds good for any plate of the kind. Undoubtedly, this is only partially possible, but it does point to the feasibility of reaching the nearest planets, Mercury and Venus, and even getting still closer to the Sun. If we were not fatigued, we could even now safely undertake a voyage there. To prevent ourselves from burning we should only have to expose the black part of the rocket's reverse surface and close the front, transparent side with burnished shutters. If we had the inclination, we could even freeze in our rocket in the immediate vicinity of the Sun."

"Amazing!" his listeners exclaimed.

"And so," Ivanov concluded, "theoretically rocket trips closer to the Sun or farther away from it are quite feasible."

"Yes," Newton confirmed, "but this conclusion doesn't apply to landing on a planet. Let us again begin with the temperature. Imagine an isolated black sphere in ether, i.e., something like a planet. It loses four times more heat than our double-surface disk, and the average temperature will be 1.4 times less (the 4th root of 4). Thus we obtain the following average temperature (centigrade) for the

different planets: Mercury, +200°, Venus +90°, the Earth, +27°, Mars, —23°, Jupiter, —138°, Saturn, —174°, Uranus, —204°, Neptune, —218°. Actually though the average temperature of the Earth is not +27°C but only +14°C or +15°C. What is the cause of this? The point is that not all of the Sun's rays are absorbed by the planet; part of them is scattered by clouds, waters, snows, sands, hills—in short, by every kind of surface. From the inconsistency in temperature just pointed out, we find that the Earth takes in about 80 per cent of the Sun's rays, scattering and reflecting the other 20 per cent back into outer space. If the other planets also threw back one-fifth of the rays, their temperatures would be respectively: Mercury, +176°, Venus, +72°, Earth, +14°, Mars, —35°, Jupiter, —145°, Saturn, —179°, Uranus, —207°, Neptune, —221° centigrade. The average temperature of the asteroids ranges from —35° to —145°C. It is difficult to assume, therefore, that with an average temperature of —35°C, the canals and seas of Mars consisted of liquid water. The average temperature there is 49°C lower than on the Earth, a large portion of the surface of which is covered with eternal ice, snow and frozen soil. Of course, the soil and atmospheric conditions on Mars are different. But if we assume them to be the same, then the average temperature at the Martian equator should be 49°C less than at the terrestrial equator, i.e., below —25°C. So where can the water come from?"

"But what about the mirrors?" a young listener queried sadly. "Couldn't they save us from the bitter cold?"

"They could, of course," Newton replied, "especially if there is no atmosphere there. At low temperatures its motion produces a cooling effect which it is very difficult to overcome. I don't, however, reject the possibility of successfully overcoming these odds with the aid of special devices which are not at present at our disposal. Even on Jupiter, where the temperature is —145°C, the cold can be successfully combated. But how to overcome the heat

of the atmospheres of Venus and Mercury, which reaches +72°C and +176°C respectively? It's lower at the poles, of course, but the terrific heat generates currents in the local oceans and atmospheres and drives them towards the poles. In addition, what gases will surround us when we land on a strange planet? Space-suits and an adequate supply of exygen would protect us from the lethal gases of any atmosphere, but where is the guarantee that our space-suits and bodies will not perish in a blaze of Bengal lights? I reject nothing," Newton concluded hopefully, "but I only want to say that we shall need to make preparations to perform long and painstaking work, if we are to hope to triumph over the hostile forces of nature. Otherwise they will crush us without even noticing us."

56. THE SHORT CUT TO THE EARTH

It was unanimously decided to steer a course back to the Earth. The attraction of Mars increasingly disturbed the even curve of the rocket's path. Since their journey would last about four months they had to cling to the greenhouse, otherwise their supplies of fruits would be insufficient. With it in tow, they found they could not decelerate hard by reversing the blast, without damaging their source of nourishment. All the same, the deceleration was dozens of times harder than during their slow spiralling away from the Sun, and it carried our travellers sunwards in a steep, contracted spiral. The greenhouse was now not behind the rocket, but ahead of it. When they began their deceleration they were 65 million kilometres away from the Earth's orbit and moving at a speed of about 25 kilometres a second, or 5 kilometres less than that of the Earth. Due to the deceleration, the speed dropped, but the rocket's fall towards the Sun tended to increase it. When they reached the Earth's orbit it should be 30 kilometres a second, i.e., equal to that of the Earth. Then, the closer they approached the Earth the more

would the attraction of the planet come into play. The increasing velocity would again have to be retarded by the retro-blast. The travellers' thoughts were constantly with the Earth, consequently their conversation during the return trip is of no interest at all to us.

The older travellers had had time to turn grey, the youths had matured.

Only the most essential observations were made. A feeling of apathy set in. They looked after the greenhouse and the rocket. Their route was so short that they hardly noticed three or four new asteroids. The difference in their speeds and that of the rocket was so great that it would have been very hard to approach and explore them. Their eyes often turned to a star as beautiful as Venus. It was the Earth. They thought constantly of it. As they drew closer it became brighter and more beautiful. Soon it turned into a splendid miniature Moon. Its crescent increased, grew as large as the Sun, and then larger still. They crossed the Moon's orbit. The Earth became enormous: four times larger and 16 times brighter than its satellite. Their native planet grew larger and larger. It began to look very familiar. Soon it occupied 3, 4, then 5 degrees in the sky. Only a few days' travelling remained. Hearts beat faster, especially those of the younger men. What would they find back on the Earth?

It was decided to flash a telegram by means of a small mirror. Ivanov telegraphed the following message: "We explorers of outer space are nearing the Earth. We have visited and studied as much space as possible between the orbits of the Earth and Mars. We found in it hundreds of tiny planets 5,000 and less metres in diameter. This is only a fraction of what we estimate to exist. We did not see Eros. The discovered asteroids provide a rich and inexhaustible source of material for establishing colonies beyond the Earth's orbit. Many planetoids contain heavy metals in ores and in the pure state. Some contain 10 per cent of gold and platinum. Judging by the composition of

these celestial bodies, we think they are fragments of one or several larger planets. The space discovered by us receives 2,500 million times more radiant energy than the Earth. It is trillions of times larger than the Earth. In several places we encountered gas rings. We have samples of rocks, metals and gases. No one has suffered injury and we ran short of nothing. Life in outer space is wonderful. There is eternal day, eternal warmth, a variety of excellent fruit, and splendid conditions for the most diversified engineering and scientific work. We shall land in the Indian Ocean, off the coast of East India. All shipping is warned....

"Spare our modesty and relieve us of any welcoming fêtes! God gave us the talent which we have shared with mankind, and that is all. We need nothing. We have had everything in abundance, including honours. Rather see that you support the geniuses among yourselves: you know very few of them but there are more than you imagine. Try and discover them. Their hands are tied because of their difficult material conditions. Ivanov."

The greenhouse had to be dismantled or left to circle the Earth in an elliptical orbit. There was not much time left, and it was decided to abandon it. The plants in the rocket and the various devices for cultivating them were also abandoned. The propellants had been largely used up and the rocket had become much lighter.

The deceleration increased. The Earth seemed enormous and covered one quarter of the sky. They had long since passed the colonies. The water tanks were filled and the travellers got into them to avoid suffering from mounting relative gravity. In short, they took all the precautions they had taken on leaving the Earth. The rocket and its instruments functioned reliably. They steered with the help of levers submerged in the water.

The rocket entered the atmosphere, the thin protective shell grew red-hot, but the speed dropped steadily as the rocket approached the surface of the ocean.

57. ON EARTH

The deceleration increased, the rocket almost came to a standstill. A slight splash, and the rocket was riding the waves like a destroyer.

They opened the shutters and portholes and the air of their native planet rushed in with a loud hissing sound. The travellers felt they were dreaming. A stunned silence reigned for a few moments. Then they clambered out of their protective baths and put on their clothing. The Earth seemed different. They could hardly tell what was greater, their joy or their disappointment. First of all, it seemed cold and damp. Their hands, feet and bodies seemed to be weighed down with lead. For a long time they were unable to lift themselves from the floor, they felt giddy and tottered as if they were drunk, especially the older men. The air with its burden of nitrogen seemed suffocating, while their voices, due to the denser atmosphere, deafened them. A motorboat sailed up and took them in tow to a ship. The travellers began to feel better and the breeze refreshed them.

Thanks to the warning about their modesty no people had assembled to pester the scientists with questions. But they did not feel well. Some began sneezing, the following day many had colds, and some went down with influenza. The sick were in poor spirits and the joy of their return to Earth was marred. The Sun seemed dim and cold. The sky was misty, the stars at night seemed few and far between and, especially near the horizon, they were dim, while the firmament seemed flattened at the zenith. Everywhere was an unpleasant smell. All the food seemed tasteless, people looked clumsy in their clothing, furniture looked repulsive, the weight was unbearable, and the mattresses and pillows hard. The travellers constantly tripped and stumbled. Forgetting themselves, they would push off with an idea of soaring away only to fall awkwardly to the ground; and their swearing was a source of laughter. People could not

understand the cause of their extraordinary behaviour and stared curiously at the strange tourists. They arrived safely in Bombay, from where they continued by train and then by airship to their Himalayan Castle.

The inhabitants of the castle, of course, were already well informed about their adventures. They were given a rousing welcome, but many were surprised to see the travellers were bruised and had sticking plasters on their faces. They couldn't refrain from laughing when they discovered the reason.

The newcomers found it unusually cold in the hills, but the Sun was warmer. Gradually they discarded their greatcoats, recovered their health and strength, the bruises faded from their noses and foreheads and they became accustomed to terrestrial life. Helmholtz and Galileo were constantly with them.

58. THE MEETING IN THE CASTLE, PLANS FOR MORE SPACE TRAVEL

The world waited impatiently for the scientists' report on their extraordinarily successful trip. Newton named the day when he and his companions would deliver their reports in the castle.

On the appointed day learned delegates arrived at the castle from all the countries of the world.

Newton, interrupted frequently by his equally learned companions and members of the audience, gave a detailed description of their adventures in outer space. He wound up with the practical conclusions to be drawn and his plans for more travel and research in the future.

"The space 34,000 kilometres from the Earth where the colonies are now being established," he said, "is inconvenient, since there is not enough materials to provide for work. I suggest therefore that new settlements be gradually transferred to the space between the orbits of the Earth and Mars, which abounds in building materials. I

have in mind very small planets invisible from the Earth. When the number of colonies increases sufficiently they will expand their industries and be able to build dwellings without help from the Earth. Material is also available in space in the form of the small bolides to be found between the Earth and the Moon, where the colonies now are, but there is so little of it, that it is not worth mentioning. For some time to come the Earth will continue to manufacture only propellants and rockets for carrying people. The rockets, after serving their purpose, will be able to return on fuel manufactured 'up there'. Our posterity will find shelter, happiness and moral satisfaction in outer space. Can human genius forecast the development of the settlements beyond the Earth's orbit in a thousand or a million years? Who can say how the colonisers will adjust themselves from the material and social point of view, as their numbers increase? Can we foresee what they stand to gain, the development of industry and science, the evolution of the human race itself? Will the Sun grow dimmer in the millions of years to come? What will the inhabitants of the sky do then? Will they find a way out? Maybe they will take off for other, burning stars? What will their journey be like? What planets will they encounter and what will they find on them? There are infinite numbers of planets suitable for habitation like the Earth."

"But that is all far away and hypothetical," one of the learned listeners remarked. "We would prefer to hear about what can be done in the immediate future."

"When we have rested, digested our vast accumulation of impressions and gathered strength," Laplace replied, "we shall dispatch a new expedition."

"Then," Newton added, "we'll head for the region of known asteroids between the orbits of Mars and Jupiter, where we should find much of interest. En route we shall circle Mars several times, and maybe visit it. It will be a simple matter to visit its two small satellites—as easy as

gaining access to the asteroids, since the gravity at their surface is low."

"If we do not become overfatigued," Ivanov said, "we may reach Jupiter and Saturn. It will be hardly possible to land on those planets, and anyone bold enough to try to do so will almost surely meet his death. But we can circle them at close range and visit their small satellites and the rings of Saturn."

"We may first undertake a trip to Venus and Mercury," Newton observed. "It is difficult to foresee how much can be done and to what extent we shall be successful."

The conference ended on the following day, the guests departed, and the castle anchorets resumed their peaceful, rational existence.

THE AIMS OF ASTRONAUTICS

The possibility of space travel has been discussed at large, both in our country and abroad.

Suppose it *is* possible—what will be the good of it? What will humanity gain from conquering outer space?

Some think of manned spaceships travelling from planet to planet, of the gradual populating of the planets and of deriving advantages from them, as in the case of ordinary earthly colonies.

Actually this process will be quite different. So far we cannot even dream of landing on large heavenly bodies, for the task presents tremendous difficulties. Even landing on a smaller body like our Moon is something that belongs to the very remote future. What we can realistically discuss is going to some minor bodies and moons, for instance, asteroids (10 to 400 kilometres in diameter).

The chief aim and the first achievement will be man's journey into the ether, the use of solar energy and of the bodies dispersed in space (asteroids and still smaller particles).

I hear the reader exclaim: "What utter nonsense! Can human beings live in the ether without a planet, without support for their feet?! Only the larger planets have atmospheres and can accommodate man."

But, first of all, landing on major planets is a difficult technical problem and only specialists can appreciate these difficulties. Secondly, we shall encounter on them

atmospheres of unknown composition, unknown plants and animals, and unknown temperatures that alone will be sufficient to destroy us. Of course the time will come when the planets, too, will be visited, but so much time will have to pass before this happens that there is no point in discussing it now.

Even if we did manage to reach all the planets now, it would be of comparatively little use. The value of a planet depends on the amount of solar energy it receives, and all the planets taken together get only ten times as much energy as does the Earth. This is an infinitesimal amount compared with the total solar energy, which is 2,200 million times that received by the Earth, and 200,000,000 times the aggregate amount which goes to all the planets of the Solar System. And this store of energy will be at man's disposal if he manages to master outer space! The achievement of this goal is *hardly* to be compared with the discovery of 2,000,000,000 new planets like the Earth.

When we have obtained a clear idea about life in the ether, we shall well understand the meaning of the word "hardly".

It would seem that nothing could be more absurd than living in a void and without any support. Yet this is not only achievable but offers advantages which it is extremely difficult to appraise correctly.

We have first to consider how man breathes there, how he builds his dwellings, how he moves about, how he breeds plants, how he lives, eats, works, manipulates machines, marries, reproduces his kind, what is the state of his health, and many other questions.

Evidently the most impossible, intolerable thing is the absence of air or atmosphere. But that is only partly true, for the atmosphere is at the same time the source of the greatest misfortunes of man; as yet man cannot control the atmosphere, its temperature, or any of its other properties. Take the temperature, for instance. In the daytime

life is all but impossible at the equator because of the intense heat. At night, it is more tolerable, but the air is humid and unhealthy. In northern countries the summer is unbearably hot and the winter as unbearably cold. What tremendous sacrifices and labours is man involved in because of this struggle against air temperature, winds, snow-falls, torrential rains, droughts, microbes, and so on! Then the atmosphere deprives man of a tremendous part of the Sun's energy, as one part of it is reflected by the clouds and the other absorbed by cloudless air. It simply robs us!

At present neither human beings nor plants can do without gases. Man needs not less than half the oxygen available at present (a density of 0.00012, the pressure being not less than 100 g/cm^2, or 0.1 atmosphere). In addition he needs a small amount of water vapour; nitrogen and other gases are not necessary, they are even injurious.

Plants can be satisfied with negligible quantities of carbon dioxide, oxygen, nitrogen and water vapour, constituting their gas nutrition. The aggregate pressure of this gas mixture is less than 0.01 atmosphere, i.e., 10 g/cm^2.

This means that if a little carbon dioxide and nitrogen is added to the atmosphere needed by man, it becomes suitable for plants.

For the time being we shall deal only with this kind of atmosphere, how to prevent it from being dispersed and to keep it pure. Actually every living being, every plant needs a special kind of atmosphere, temperature and soil, but we shall disregard this for a while.

Ordinarily, a spherico-cylindrical metal vessel capable of withstanding inner pressure weighs ten times as much as a gas having the elasticity of oxygen contained within it. Suppose that 100 cubic metres is space enough for one man. One cubic metre of oxygen will weigh about 0.00012 t, 100 cubic metres—0.012; the container will weigh 0.12 t, or 120 kg, i.e., its mass will be twice that of a man.

To spend 120 kg of glass, steel, nickel and other hard

metals on constructing a home for a human being is a mere trifle. There would be no harm in spending ten times as much.

How is such a dwelling constructed? It is cylindrical, closed at each end with half-spherical surfaces. The more spacious it is within, the thicker will be its walls. To make the thickness of the walls a practical proposition, the dwelling is built for several thousands or hundreds of persons. It consists of a spherico-cylindrical surface, which shines both within and without. A third of the surface turned towards the Sun consists of latticed window panes. It can be likened to a curved window-frame.

What are the best shape and dimensions? A sphere is not convenient because it is not particularly easy to arrange for communication between spherical surfaces. Very long rounded (cylindrical) surfaces seem to be the best. Thus the dwelling will have the appearance of a tube of indeterminate length.

What will be its diameter? The greater the diameter, the less sunlight there will be per unit of volume, that is, per inhabitant. A large diameter is, therefore, a disadvantage because sunlight feeds plants, and plants supply food for the people. Neither is a small diameter any better as it hampers movement, restricts space and does not allow thick plating. We may take a diameter of two or three metres but it can, of course, be much larger, depending on the purpose of the dwelling. Assembly halls, factories and other public buildings will be enormous. Their purpose will determine their size. Just now we are concerned with the family—where it will live and what it will eat. Our calculations show that the skin of a cylinder with a diameter of three metres will be too thin for practical purposes. But there is nothing to prevent our making it ten or a hundred times thicker. Its strength will increase in proportion and we will not economise on material.

In addition to the advantages in regard to light, a thick-walled tube has others: the smaller the diameter, the

greater the number of isolated compartments. This minimises the risk of loosing all air and perishing in space.

Suppose the dwelling is three kilometres long and its diameter, three metres; it can then be divided into 300 compartments, each ten metres in length, three in width and with a volume of 70 cubic metres. This will make a sizable room, large enough for an average family. Its lighted area will be 30 square metres—quite sufficient for the garden that will provide the family with food.

Why is this less risky? Suppose a compartment develops an air leak; the manometer will instantly show this; the family moves into the neighbouring compartment and the damaged one is isolated from the rest. It is then inspected inside and outside by people wearing space-suits and the leakage is repaired. The family then returns to its home. So it is clear that the more compartments there are, the less the danger. Special devices may be installed to indicate automatically the cracks through which air is escaping.

The air in the compartment would become foul but for the plants and the soil they grow in. In this miniature world, the family compartment, the same cycle which purifies the air and the soil takes place as that on the Earth. We will give more details when we describe the growing of plants.

Now let us examine the temperature in the dwelling. With the construction just described and at a distance from the Sun equal to that between the Sun and the Earth (i.e., the Earth's orbit), a suitable temperature is possible only when the dwelling rotates and the windows alternately face the Sun, or are turned away from it, i.e., when day and night alternate. Another method is to have part of the windows permanently facing the dark side, with approximately 0.1 of the total inner area in sunlight (0.3 of the projection).

The temperature will be wholly controlled by man who will be able to change it from —250° to +200°C, depend-

ing on what amount of the Sun's light is used. He will be able to reproduce all climates, not of the Earth alone but of every planet in the Universe.

There is one hitch, however, and it is that, for economy's sake, as much solar energy as possible must be utilised through plants or by some other means. Yet if this is done the temperature will reach 200°C above zero and everything will be burned up. On the other hand, it would be a pity to lose light by turning away from it. The remedy against this is simple: to move to a more remote orbit, one between Mars and Jupiter but closer to the former. If the orbit is removed twice as far as the Earth is from the Sun, the amount of warmth will be just enough for man and plants to thrive. It will then not be necessary to turn away from the Sun and reject its gifts.

We can spend some time on the Earth's orbit but that will be extravagant. The sunlit area at twice the distance will be four times greater than at the Earth's orbit; there we shall find plenty of material as it will lie beyond Mars, in the asteroid belt. (A method that is not extravagant would be to utilise the whole of the Sun's energy without moving away from it.)

Now let us see how the Sun will treat us and what conditions it will create for us in our dwelling. We still have an eternal day or eternal night, or an alternation of the two just as we please. For instance, plants may have a permanent day while man who, owing to the Earth's rotation is accustomed to sleeping at night, may set up a screen and sleep in the dark. Then we shall always have excellent weather and any temperature we like. This will make clothing and footwear unnecessary. We shall be amply supplied with vegetable foods. There will be no fear of catching infection as the atmosphere will be free from harmful bacteria, or, should the need arise, any compartment can be isolated and disinfected by simply raising the temperature to 100°C or more. Even at a double distance from the Sun it will be possible to raise the

temperature considerably, but we shall deal with this later. Is there any comparison between this and our unfortunate Earth!

There is one very important circumstance, a priceless gift of ethereal space, the absence of gravity. Mass is there all right, but gravity seems to have disappeared.

Our dwelling moves in space at a speed of several dozen kilometres a second, or several million versts a day, depending on the distance from the Sun (the nearer we are to it, the greater the velocity, and vice versa). But we are totally unconscious of this motion, just as we do not notice the movement of the Earth. We feel as though we were perfectly stationary.

We experience the gravitational pull from the Sun, the planets, the stars and other heavenly bodies. But we do not feel it, as we do not feel the Sun's attraction on the Earth where we are conscious only of the Earth's gravity. In our dwelling we are far from the Earth; instead of the Earth there is the tiny mass of the tube, so small in fact that it has no perceptible force of attraction for us.

The attraction of the Sun and other heavenly bodies makes us fall towards them, and therefore, describe a curved line like that described by the Earth. But our dwelling and we ourselves are falling in the same way, so we do not notice it, just as on the Earth we do not notice that we are falling towards the Sun.

Gravity seems to be absent as motion is evidently absent. If we have not produced them ourselves, then there is neither gravity nor motion. What are the consequences? The bodies do not exert pressure on one another and do not fall. A building, even if it is several kilometres high, cannot fall to pieces or fall down. So in construction one has not to overcome gravity. Parts of a building will exert perceptible pressure on one another (owing to reciprocal attraction) only if it is on the planet scale of several hundreds of kilometres high. Where there is insufficient resistance of the material, the parts press close together and

become destroyed. But even a destroyed building cannot fall anywhere, just as the Moon does not fall on the Earth and the two together do not fall on the Sun. Bodies can remain suspended without any support and without touching one another. Their direction relative to rest is quite arbitrary. For instance, we in our dwelling can hang in mid-air (without a rope or other support), our heads turned towards the Sun, or away from it, or in any direction we choose.

There are no weights, there are only masses. We can hold any mass in our hands and feel no weight. No matter where we put the mass—on our head, on our back or under our feet—we do not feel it.

It is clear then that we can dispense not only with clothing and footwear but also with furniture. What need have we of chairs, armchairs, beds, mattresses, pillows and so on, if there is no need to lean against anything, if nothing presses against anyone, if every place is "soft" in a way that the finest of feather beds cannot be soft.

Why pack tender fruits, glassware and other fragile objects in straw, sawdust, cotton-wool or rags, if there is no reciprocal pressure? Is not all this the great advantage of life in space!

There is no above or below. Until one gets accustomed to this, what is over one's head is above and what is underfoot is below. So above and below are interchangeable at will. Fancy finding yourself without a support and a yawning chasm under your feet! Gradually, however, the illusion of above and the fear disappears. But in the early days a dwelling with walls and a floor and even physical contact with them are essential to soothe the nerves.

Now let us consider motion. We shall not discuss absolute motion, which actually is non-existent, but of motion in relation to the Earth, the Sun or some other body; nothing is known of absolute motion. We shall also leave aside our planetary movement (our dwelling is racing through space like a planet), i.e., its movement in relation

to the Sun. We do not notice it so for the time being we shall not talk about it. We have in mind only the movement we ourselves produce by means of our muscles, machinery, or in some other way.

We shall consider that the aggregate dwelling of great length and breadth, huge in volume, is stationary, just as in speaking of man's movements on the Earth we presume the Earth to be in a state of rest.

Let us imagine that we are in a spacious hall, experimenting with movement. In the centre of the room there is a big stone, a table, a chest of drawers or some other object the parts of which are not in a state of interaction or motion, as with a working machine or an animal; that is, we have in mind a single solid inorganic body.

It will cost us much effort to place the object (a table) so that it is immobile. Once this is done, what next? It will remain stationary for ever, which is to say, it will not rotate or change its place in relation to the walls of the dwelling. It will remain for all eternity in the position in which we have placed it.

The same could be done with a human being—he can be fixed in one place and asked not to move his limbs. In such a case, he will not move closer to or farther from the walls.

Then we give him freedom of action and ask him to move his arms and legs, come towards us—and what do we find! He will writhe about, move his arms and legs but still remain on the spot (if he is in empty space). He waves his legs and arms about freely, squirms like a squashed worm, moves his head to right and left, tries to sit down, to stand up, stretches his limbs in every direction, but his centre of gravity seems nailed to the spot. He remains where he was and has not advanced by as much as a centimetre.

We ask our friend to spin around as children like to do; with the best will in the world he is unable to perform this act. When tired out he is quiet again, his face is

turned in the same direction as it was when first we put him in position. The position of his body has not changed either.

If this is the state of affairs, how is one to move about, to change one's position and move in different directions? Nothing could be easier. It is possible to move about in every direction, both in a gaseous medium and in a void. In a geseous medium the palms of the hands are used like wings; we would soon learn to push the air with them and turn around or move in any desired direction. But hands are poor wings, because their surface is too small. With the help of light plates, about a metre square, it is possible to turn round and move at a great speed. The wings can be even smaller—there will be no gravity to overcome, for inertia and friction will be the only factors to contend with. This will require the minimum effort for ordinary speed, that of a pedestrian.

There are other methods that can be used both in an atmosphere and in a void, but which are indispensable in a void, for there no other means are available that can be of any use. In the air medium of our dwelling the wings will be quite sufficient. But we shall continue our experiments in the big hall, ignoring the resistance of the medium which is not great at ordinary primitive speeds of man.

We have seen that man could not set himself in motion, i.e., impart to himself either translational or rotatory motion, or even to turn his body in a different direction. All he achieved was a haphazard movement of the limbs. In the long run he found himself in his original position.

But let us imagine he is wearing clothes. He takes off his hat or coat (he can do this) and throws them aside; the objects fly away, but he also slowly moves off in the opposite direction until he hits against a wall. But for this obstacle he would have moved on eternally, smoothly and in a straight line.

The greater the mass of the thrown object and the greater the force with which it is thrown, the faster the man moves from place to place. If two men of an equal mass were to repulse each other with equal force, they would move apart in opposite directions with equal speed. If one man were repulsed from two men or from double his own mass he would move at twice the speed of the other two.

The difficult thing here is to avoid rotating: the movement of the masses repulsed from one another is accompanied by rotation. Their movement, in general, is like the movement of a cart wheel, a spinning-top or a planet. Theoretically, however, repulsion without rotation, that is, pure translational movement, is also possible.

Let us consider rotation as such. We shall again turn to our dressed man. Ask him to take off his hat or boots and spin them like a top. The hat or the boot spins round but the man, too, begins slowly spinning. He spins round like the hat, only in the opposite direction. The greater the mass of the object he has spun and the greater the speed with which it spins, the faster the man rotates. If two men of similar shape and mass were to set one another spinning their angular rotatory velocity would be the same. But if one were spinning round his vertical axis and the other round his horizontal axis, the latter would spin more slowly, as the moment round the horizontal axis is greater.

In air, of course, rotation will stop sooner or later owing to friction. But in a void it would be eternal and uniform, like the movement of the planets. And the two men would go on spinning in space like two dolls, and all their will-power would be unable to destroy this motion or the translational movement. But if they come into contact with each other again then the rotatory movement of both will stop, they will cease to spin.

Let us imagine a group of people without a support, perfectly motionless and not rotating. Their common centre

of gravity is stable. The moment of circular movement is zero for all time. But each one of them can make grimaces and strike different attitudes. The movement of their muscles is as free as on the Earth. By pushing away from one another, any of them can obtain all forms of rotatory or translational movement. If one of the group is given rotatory and translational movement and he cannot catch hold of the group (or is not roped to it) then he will never lose either form of movement. He will become a spinning-top for all time, and will be separated from his friends for ever. He will move eternally, uniformly and in a straight line. He will cover thousands, hundreds of thousands of kilometres and will never stop. The members of the group may wander in space at will but their centre of gravity will remain in one spot.

In order to stop the movement translational or circular motion (in reverse direction) has to be imparted to some other body within reach; if this opposite movement is insufficiently strong, the movement of the main body will merely slow down; if it is sufficient, the main body will stop; and if excessive, its direction will change.

So it is clear now, how movement in air is started and stopped. Inside the dwelling it is possible to push off from the walls, from different objects and from the air with the help of small wings which, of course, have no weight. In a void the task is more difficult and dangerous. Here some kind of support, not necessarily connected with the dwelling, is essential. A rocket, compressed gas or vapour, or any solid or liquid body can be used.

It is possible to dispense with a movable support and the throwing of objects (which leave us never to return), if attached to the dwelling by a rope or a cable. We can then push ourselves from it in the desired direction and fly away until the rope pulls us up short. Then, in order to return, we pull ourselves back by the rope to the dwelling.

Thus, movement in ethereal space, in a medium without gravity, can be of three main kinds. Uniform and even

without rotation, circular with a stationary centre of gravity and axis of rotation, and the mixed kind, i.e., a combination of the rotatory motion and perpetual translational movement along a straight line.

There is circular movement of a more complex type, with the addition of vacillation of the axis of rotation. This type, however, is unstable, that is, not eternal, and tends to be gradually transformed into simple rotation round a free axis.

We have left out of consideration the complex bodies whose parts are movable, and also living bodies. Both can eject visible and invisible particles. And so, the laws of motion already indicated would seem to become violated. For every animal regularly excretes various substances, such as vapours and gases, and can therefore be likened to a jet device. In our dwelling, a man who is at first quite motionless will acquire a little rotatory and translational movement, due to the effect of ejected gases and vapours, of the irregular blood circulation, the heartbeat and the movement of other organs. But this will only be so after a considerable period of time.

Where there is no ejection, then all bodies, no matter how complex, whether animate and inanimate, are subject to the following three rules:

A. If the centre of gravity of a complex body is in a state of rest, this state of rest cannot be disturbed by the body's internal forces.

B. If the centre of gravity is in motion, the body's internal forces cannot change either the magnitude or the direction of the motion, i.e., the motion will be perpetual, uniform and along a straight line.

C. There is a third, extremely important law pertaining to the rotation of a complex body, the relative positions and motion of whose parts constantly change: the rotatory moment of inertia of such a body continues invariable for all time (concerning moments of every kind, refer to a textbook on mechanics).

This law is applicable to contracting suns, nebulae planets and solar systems. Its application is truly universal. For instance, if a group of people hold hands and move round in a circle and draw closer together as they move, the velocity of their motion will increase as they come closer together and the group becomes more compact, and vice versa. Given this condition, both angular and absolute velocities will increase.

But what are the sensations of a man rotating in a circle or moving without rotation? Let us go back and observe him or ourselves inside the dwelling. Being unaccustomed, we are not conscious of translational movement and it seems to us that not we but the walls around us are in motion. Neither are we conscious of our own rotatory motion—again it seems that the room is rotating. To us it appears as though somebody is revolving it. We Earth dwellers go round with the Earth, move forward with it and have many other motions in common with the planet. And we feel that these are not our own motions but the movement of the heavenly bodies surrounding us. What we are conscious of are the movements which we ourselves produce. Most of the Earth's motions do not exist as far as our senses are concerned.

But in the ether we produce our own, even the slightest, movements. Why then do they seem to lie outside us? The reason is the smoothness of this kind of motion, the fact that it is imperceptible because there are no jolts, vibrations or other effects accompanying the terrestrial non-ideal rotation and motion.

Nevertheless, in time these illusions should disappear at any rate in the dwelling. On a boat it seems to us, at first, that the river banks are moving; gradually, however, we become conscious of the motion of the boat, no matter how slow and smooth. It will probably be like this in the ether.

So far we have been talking about rest and motion inside the dwelling. What about our sensations outside in

the immense Universe, under the bright and scorching rays of the Sun?

We can see quite a lot through the windows of our dwelling. The sky is black. The patterns of the constellations are just as we see them from the Earth, only there is less of the red tint in the stars and a greater variety of colour. They do not twinkle or shimmer, and if the eyesight is good, they look like lifeless dots without any rays. The Sun is somewhat bluish, the Earth is like a star—like Venus—and the Moon is hardly discernible. The pattern of the constellations does not depend on our position in the Universe but is always the same seen from Jupiter or Mercury; but the Sun preserves its visible size only along the orbit of the Earth.

As there is no atmosphere the stars, nebulae, comets, planets and their satellites are seen extremely clearly. Bodies visible from the Earth only through a telescope can be seen here with the naked eye. But things that can never be seen from the Earth with a telescope become visible.

We can leave our dwelling in space-suits with an oxygen supply and an apparatus to absorb human excretions.

We have chosen the shady side. The Sun is not visible. The picture before us seems very strange. We feel we are the centre of a small black sphere spangled with varicoloured dots, stars and nebulous spots. Across the entire sphere there stretches the broad hazy band of the Milky Way branching off in some places. Whenever we try to avoid the Sun we find ourselves in the midst of night. If we move away from the dwelling but do not leave its shadow, we can see almost the whole of the celestial sphere at once.

We would be killed by the Sun's ultra-violet rays, but the glass of our space-suits and the dwelling protect us from them. On the Earth we are protected by our atmosphere.

Out of the shade we can see the Sun. It seems to have grown smaller compared with what we see on Earth; it has dwindled just as the celestial sphere has, but this is a subjective impression for, actually, it is as large as ever.

It is hard to imagine the feelings of a human being in the midst of the Universe, in the centre of this woebegone black sphere adorned with bright coloured spots and smeared over with a silvery mist. He has nothing underfoot, nothing overhead. Perhaps he imagines that any minute he will fall to the bottom of this sphere, to where his feet are.

After pushing off from the dwelling he will move along a straight line and to all intents and purposes should find himself leaving the dwelling never to return. But this is not quite so. The Sun's gravitation will make him revolve round it regardless of the direction in which he moves. So the line will be not straight, but curved. One degree of the circumference (at the distance from the Earth) is equal to more than two and a half million kilometres, and the man's path may be regarded as straight for hundreds of thousands of kilometres. If the man covers a metre a second (walking pace) his path for several years will be as straight as an arrow. It will take him 30,000 years to complete the orbit but he will pass so far from his dwelling that he will not notice it.

But if by that time humanity has spread all over the vast celestial sphere and has constructed dwellings and other buildings in outer space, the individual who has left his own dwelling will not be helpless for he will meet people and their buildings all along his path; he will receive information and directions and find his way back to wherever he wants to return.

How enormous is this field of the Solar System, this sphere which mankind can occupy! At a distance from the Sun exceeding twice that of the Earth its surface is 8,800,000,000 (almost 9,000,000,000) times greater than

the surface of the largest section of the Earth (its projection) or 2,200,000,000 times more than the entire surface of the Earth. This sphere receives equally as many times more solar energy compared with the Earth.

The Earth does not receive all of the solar energy sent to it, because more than a half is reflected by the clouds, part is absorbed by the atmosphere, another part falls on oceans, deserts, mountains and snow-fields where it is of little use, and slightly more than 10 per cent reaches the Earth's surface. Thus the value of the sphere, of its eternal day, of the virginal rays of the Sun, is ten times greater and is expressed in the additional amount of solar energy of 22,000 millions compared with that of the Earth.

Even this figure cannot define the spaciousness of this sparkling sphere: it is many hundreds of millions of times greater than the Earth. The most important thing, however, is not its size but the amount of available solar energy.

Motion and its laws outside the dwellings and inside them are the same, but the sensations of human beings are quite wonderful.

One is not conscious of translational movement which is ascribed to the surrounding, artificial, man-made bodies. It has absolutely no influence on the position of the stars and planets. So if no people with their buildings are visible, everything seems to be stationary.

But strictly parallel translational movement is difficult to obtain. It would be imperceptible, if it were not accompanied by rotatory motion. If the latter is slight the human being does not ascribe it to himself, but believes the black celestial firmament is rotating—the axis on which our body revolves becomes the axis of the Universe. Thus, if we revolve round our vertical axis we shall have one pole overhead (with a "polar" star) and the other underfoot. All the other stars will describe circles simultaneously with the man, so that if the man completes his circle in ten minutes the astral sphere will complete its circle

in the same time. Rapid rotation may cause dizziness, illness and even death. It will therefore manifest itself to man by its consequences.

Then the illusion of above and below will be difficult to discard. We shall continue to regard what is over our heads as being above, although the head may be constantly descending and ascending if the body is rotating round its horizontal axis. It will appear to us that the stars are falling and rising all the time. We do not believe in the descent of the head; it is, as it were, immobile and what is over the head is above.

The void and absence of support under the feet also frightens us. There is the constant fear of falling down into the void; it is a perpetual surprise to have no floor or ground underfoot.

We are not concerned here with the beginnings of life in the cosmos. It starts on the Earth. The first dwellings, tools, machines, plant nurseries, workmen, etc., all come from our Earth. We can only here describe the gradual transition of the emigrants from our planet to a life in outer space independent of the Earth; the development of their industry and the population of the celestial sphere. At first the colonial population consumes the supplies that are brought from the Earth and only step by step do they become independent, prosperous and spread all over the sphere.

We are supposing that the initial stage is over. We now have to describe what life is like there. What preparations were made for it on the Earth and how everything was brought to the ether do not concern us.

Perhaps the absence of gravity will prove injurious to human health? Gravity makes the blood flow to the legs and feet, while if there is no gravity the blood will flow to the brain. So a human being with weak blood-vessel walls (inclined to apoplexy) risks dying if he is immersed in water, or assumes the recumbent position or, especially, if he stands on his head.

In water or when lying down the blood pressure becomes almost uniform just as it does in the absence of gravity. So the absence of gravity is as harmful, or as beneficial, as lying down. The sick and the weak will benefit from it, it is even essential for them. A medium where there is no gravity is little short of paradise for the sick, the doctors and people who have no legs: indeed, there are no bedsores, one has access to all parts of the body and all movements are effortless. A healthy person soon finds lying down intolerable, but this is chiefly due to the physical inactivity of lying down. If he could exercise his muscles while lying in bed, the tediousness would disappear. It is boring to lie on one's back: there are no new impressions. But in a medium without gravity the work of the muscles depends entirely on us.

Gravity enables us to swallow our food and to excrete. But these functions of the organism can be performed in the horizontal position as well. So gravity is not absolutely necessary after all. Acrobats can drink and eat even standing on their heads—and there is no deception about it.

The upright position we maintain on the Earth is responsible for certain diseases, so too much of it is even harmful.

In the ether dwellings, baskets, shelves, stands, racks, etc., to hold plates and dishes, various household objects and other things will be unnecessary. But in the absence of gravity the slightest effort, even the inevitable movement of the air, will be sufficient to start them all wandering about the rooms like animated things, or like specks of dust in the air. And this is intolerable and dangerous: while breathing a man may get a pea, a nail or a pin in the throat which may prove fatal. But all kinds of small objects can be kept in light packets, boxes and sacks. For bigger objects there will be nets to hold them. The least force will suffice to hold them in place. Objects may be also kept tied on short strings.

And what about the soil for the plants? With the slightest jolt, friction, movement, air current, especially if it is dry, it will be dislodged and carried away into the air in the shape of floating specks of clay, grains of sand, lime, etc. This, also, cannot be tolerated. On the Earth strong winds carry away not only dust, which is always present, but largish grains of sand and even small stones, leaves, insects, and so on. But where there is no gravity, this will occur more frequently and will be much more serious. Of course, before it can be breathed in, air must be sieved through nettings, fabrics and various liquids.

All that, however, will not be enough: artificial gravity will have to be created by some means or other. There is no need for it to be as great as on the Earth and so burden people with the effort of combating it. Gravity equal to one-hundredth or one-thousandth of what we have on the Earth will be quite enough. Let us deal with the smaller figure. What makes it insufficient? The effect of it will be to make all large objects fall to the artificially created region below, i.e., to the floor, for with gravity there will appear a floor, a ceiling and slopes. The falling-down will proceed slowly: in a second a body will fall half a centimetre, in 10 seconds—half a metre and in a minute—18 metres. We see that a minute will be enough to clear the largest room of its wandering bodies, both large and small.

A weak gravity will be especially important for buildings where plants will be grown, in order to keep the soil in place. Dust, sand and even larger bodies roaming about present no danger to plants, but they are nevertheless harmful as they obscure the sunlight. Besides, how can plants live if the soil is dispersed into the air?

In the ethereal medium it is very simple indeed to obtain constant artificial gravity. However if the gravity is considerable, the dwellings and premises for plants should be made a little more durable, a little bulkier than in its absence.

Gravity appears due to the rotation of a body; in empty space a body rotates forever. So gravity will be constant and uniform and will require no effort. The higher the velocity of the particles describing a circle and the smaller the radius, the greater the centrifugal gravity, and vice versa.

Now imagine a long conical surface, a kind of funnel with the base or wide orifice, closed by a transparent spherical surface. It is turned towards the Sun and the funnel rotates round its longitudinal axis while a layer of moist soil is distributed on the cone's non-transparent inner walls, where plants are grown.

This is how solar energy can be utilised without extreme rise of temperature even at a distance as long as from the Earth to the Sun. The longer the cone and the larger its area (with permanent transparent base), the lower the temperature within the cone. At the Earth's distance, this area should be about four times that of the glazed surface. To get this, the generatrix (a little larger than the longitudinal axis) should be twice the diameter of the base. Closer to the Sun the cone should be longer, and farther from it, shorter. Even in close proximity to the Sun the temperature of the gases in the cone can be made to suit the plants. For instance, at a distance one-tenth of that between the Earth and the Sun the cone should be 100 times longer—its base diameter being 1/200th of the height.

The trouble with cones is that passages between them are more difficult to construct than between the cylindrical human dwellings we have already described.

It would be advisable to construct buildings for plants separately from human dwellings, because they do not need a dense atmosphere and strong walls. This means a saving in building materials while a special, somewhat rarefied, atmosphere makes for excellent yields. Should some of the plants chance to die because of gas escapes, this would not be very important. True, there is the difficulty about getting human excretions to the hothouses, and the prod-

ucts of plant life (gases, fruit, etc.) to the human dwellings.

In the cones sun-rays fall on the plants obliquely, so their effect is weakened. Inside the cones there is eternal day and also eternal spring with a fixed temperature best suited to the plant growth. The rotation of the cone which gives rise to gravity keeps the moist soil and vegetable residue in place. Ripe fruit will fall down to the soil and not float about in space inside the cone.

In human dwellings and in other buildings some sort of gravity could also be of use. A gravity equal to one-hundredth of the Earth's will in no way hamper movement and different working processes. Let us suppose we have a spherical building two kilometres in diameter. The sphere rotates slowly with the velocity at the equator of about 10 m a second. The sphere completes its revolution in 600 seconds, or 10 minutes. The greatest gravity at the equator amounts to one-hundredth of that of the Earth. A leap from the inner circumference to the centre lifts a man 100 m, so gravity is imperceptible and movements are not hampered.

The phenomena of motion in such a sphere are complicated and we shall not describe them here.

The types of human dwellings and buildings for plants can be infinitely varied and for the time being we shall leave this aside, too.

We shall explain what is very important: the way in which a definite temperature, moisture and air composition, and good food for the plants and human beins are obtained in the combined dwelling.

The slow rotation gives rise to gravity, gets rid of rubbish and ensures order in the dwelling. The glass in the windows is thin (quartz or some other material), highly transparent, letting through, as far as possible, every kind of rays. The rays are tempered down by the glass and the thickly growing plants so they cannot harm humans. The plants chosen are fruit-bearing, with plenty of foliage,

dwarfish, without thick stems or any parts which do not need sunlight. The more they make use of the sunlight, the more they produce fruits, turning to the best account solar energy and heat. The heat is returned, since the human beings eat the fruit and release into their dwellings the heat assimilated by the plants. When fruit is stored the heat is for a time withheld from circulation.

There should be as many plants as will produce (through their leaves, roots and fruit) the quantity of oxygen consumed by the people living in the dwellings. If consumption exceeds production the people suffer from lack of oxygen while the plants grow better thanks to the surplus carbon dioxide; if more oxygen is produced than the people need their breathing becomes easier but the plants do not receive enough carbon dioxide and grow weaker. With a happy choice of plants the equilibrium is maintained automatically. Another important factor is the number of people in the dwelling: this must be in conformity with the number and properties of the plants.

What about the water which both plants and human beings greatly need? The quantity of water will remain constant, neither increasing nor decreasing. But how will this be brought about? Plants, animals and soil transpire water all the time inside the closed building and the vapours cannot escape from it, so they will be condensed in a refrigerator and accumulated as water. There will be rooms on the shady side of the dwelling with various low temperatures. Any room can be turned away from the Sun and isolated from the internal heating arrangements (just like household cold-storage cellars), and the low temperature desired is easily obtained. More or less moist air is passed to these rooms and leaves as much vapour there as is required, this depends on the speed of circulation and on the temperature. Both can be controlled.

The water from the refrigerator is used for drinking, bathing, watering the plants and moistening the soil. Air, too, constantly circulates with the water between the plants

and the refrigerator, and back. It is passed into the soil by special tubes and, having passed through the roots and bacteria, is released into the atmosphere purified and fit to be inhaled.

Human excretions are diluted with water and also go to the soil where bacteria quickly make them suitable for plant consumption.

In these dwellings no regular supplies of water and food for plants and animals will be needed. The established quantity of gases, water, soil and fertilisers will serve all purposes and never become exhausted.

The same thing takes place on the Earth, only on a larger scale. But there, the fertilisers are carried into the oceans and it takes time for them to be brought back. In the space dwellings, however, no sooner are they used up or stored in the fruit than the people and animals return them and there is no loss at all. The time will come when on the Earth, too, it will be found to be advantageous to isolate plants with their supply of food and water. It will be done first of all in the deserts where there is a dearth of food and water.

So within the space dwelling the atmosphere is pure, the air is as moist as desired, even the composition of the atmosphere can be controlled. There is an inexhaustible supply of distilled water, oxygen, warmth and food. There will be no need for clothing.

There is no gravity, feet do not swell, branches are not bowed down by the weight of the fruit. In the plant sap circulates freely, since there is no gravity to overcome.

Although a little gravity has been created artificially it is so insignificant we can ignore it; the human beings living there may be considered as inhabiting gravity-free space.

The temperature in the dwelling can be regulated at will—so where is the need for clothing? <...> Of course one is at liberty to cover oneself: some people's bodies are unsightly, deformed or old and ugly. If the community

does not object, anyone may wear any kind of clothing or ornaments.

But a suitable temperature can be given at a moment's notice to a chilly aged person, to invalids or premature-born babies. The wishes and nature of the inhabitants have, of course, to be considered: some people from the tropics, the old and infirm, the invalids may want a temperature of 30°C; others—25°C and some even 20°C. Any temperature can be obtained in any building and different temperatures can be established in one and the same dwelling. When the people go to bed, they want higher temperatures, for there are no mattresses, pillows, blankets or pyjamas. When many people are assembled in one room with the temperature being 30°C, for some it will be too hot, even without clothing, for others about right; but if the temperature is fixed at 25°C the feebler people will be cold. In this case, those who are cold will have to wear some clothing.

Temperature control and direct sunlight will be used for a great variety of purposes: for instance, disinfecting the soil, the atmosphere, the walls and other household articles. For this, the plants and people will be evacuated and the temperature raised to 100-200°C. All living organisms will, naturally, be destroyed; that is why agriculture there becomes easy, for there will be no pests and only pure crops from the desired plants will be grown.

Plant selection, suitable temperature, atmosphere and nutrition will lead to marvellous harvests of excellent fruits. This will require no effort as there will be no weeds, pests, droughts or excessive rainfall.

Such chemical processes as fermentation involved in the production of alcohol, vinegar and other substances require a definite temperature. This is easily provided. The factories can produce any temperature not exceeding 200°C, in buildings not unlike the dwellings. To get a temperature above 200°C, special apparatuses are used, where heating is also produced by the Sun alone.

Water and various fruits, completely free of every kind

of infection satisfy hunger and slake the thirst. There are no chills, no infectious diseases. Bathed in sunlight, the human body is gradually freed from noxious bacteria. As time goes on, humanity will become liberated more and more from all the harmful influences with which mankind is born at present.

Once man has a dwelling with the desired temperature, a virginal sun, day and night whenever he chooses, plenty of water (a store that remains constant) and food, no need of clothing, and can move in any direction without an effort, what more can he want?

First, the human being reproduces his kind, because this is an advantage (with a larger population the social system is more perfect, there are more geniuses who can become leaders). But this means that more dwellings will be needed and material from which to build them. Secondly, man is constantly studying matter and the Universe, so he must have the same apparatuses and instruments that are in use on the Earth. Man perfects plants and himself, and for this he will always be requiring new apparatuses. But to manufacture them a great number of factories and workshops, pursuing the same aims as on the Earth, will be necessary. Household articles will be different, but that is inevitable, and books, too!

In the beginning the materials will come from the Earth. But transporting them from the Earth involves a tremendous effort; it is much simpler to bring them from the Moon or some smaller planets. It would be still easier to utilise asteroids with diameters of a few kilometres, and even smaller heavenly bodies of which there are countless numbers in interplanetary space, particularly between the orbits of Mars and Jupiter.

Minor planets have no atmospheres or liquids, but they have any amount of hydrate and constitutional water, gases, metalloids and metals of all and every type. The only thing to be done is to decompose the minerals that are in a dry state.

For this mechanical forces will be required; where are these to come from? The amount of mechanical force in the ether is 2,000 million times more than on the Earth. It comes from solar radiation and can be utilised either through the agency of plants or directly. The Sun will help man to obtain wood, charcoal, starch, sugar and an immense variety of other substances derived from plants on the Earth, all of which are sources of power, like coal, waterfalls and wind on our planet. Methods of employing the energy from these sources in the dwellings where there is oxygen will be similar to those used on the Earth. But it is inconvenient for the air will soon be polluted.

So perhaps it will be better directly to use solar heat instead of the heat of burning. We cannot do it conveniently on the Earth for various reasons: the bodies heated by the Sun are cooled by the air and wind; the Sun shines only in the daytime and even then is often hidden by the clouds; half of the heat coming from the Sun is absorbed by the atmosphere; the intensity of the rays changes with the changing angle at which they fall; there is no natural refrigerator with a sufficiently low temperature; the mirrors collecting heat quickly lose their lustre under the effect of air and moisture, then they are heavy, fragile, expensive and not big enough. All this makes the use of solar thermal units impracticable in the conditions obtaining on the Earth.

The situation is quite different in ethereal space free from gravity. No mirrors are needed in order to get 200°C above zero in one spot and 270°C below, in another, only a metre distant. This makes it possible to use highly efficient steam engines working on the steams from water, ether, alcohol and other liquids.

Obviously the engines are mentioned here by way of example and actually they may be of an entirely different type. Here is the description of an elementary steam engine. We have two vessels of the same size and shape, thermally isolated from one another. One vessel is turned to-

wards the Sun and the other is placed behind it, in the shade. The front of the first vessel is black, that is, it absorbs the sun-rays well. The dark surface and the liquid in the vessel become heated by the Sun; the temperature does not exceed 200°C. Before passing to the rear vessel—the refrigerator—the vapours of the liquids pass through an ordinary steam engine or turbine. With the proper choice of liquid and type of engine, the efficiency can easily reach 50 per cent. Such a machine will yield over one hp per metre of dark surface facing the Sun.

When almost all of the liquid has passed from the first vessel (boiler) into the second (the refrigerator), the latter is turned towards the Sun and the former placed in the shade. The roles of the two identical main parts of the installation change automatically approximately every hour, depending on the capacity of the vessels. These, of course, are made up of tubes like a woven fabric; there will be no loss of the liquid because the whole system will be securely sealed against escape of steam.

We cannot tell as yet, what types of motor will be in use; there will probably arise many types and systems which cannot be foreseen at present.

The vessels may be of any size as there will be no gravity to limit it. So they can generate any amount of power.

This is what industry will be like.

A. The elementary components such as gases, liquids, metalloids and metals, will be extracted from minerals.

B. The elements are used to produce the essential, or useful, compounds—gases, perfumes, dyes, drugs, foodstuffs, acids, alkalis, salts, fertilisers, alloys and the like (sometimes both the elements and the necessary compounds are found in nature).

C. The alloys, various building materials and solid substances in general are processed and made into tools, lathes, machines, utensils, scientific instruments, paper, fabrics, clothing, space-suits, dwellings, factories and so on.

To effect the above (A, B, C), we on the Earth use the method of raising or lowering temperatures and pressure, electricity, catalysers (substances used in minute doses to accelerate chemical processes), and mechanical forces.

The required tools are already in use on the Earth and will be delivered into space.

At first man, like animals, had no tools, then very simple ones were made; with their help man made better ones, and so on and on, until he learned to make the modern machines that fill us with profound amazement and admiration. Progress in this sphere will never come to an end, and in the ether tool-making will develop along perfectly new lines, in keeping with the new conditions.

We know how high temperatures are obtained on the Earth, but in the ether these methods will be needed only in exceptional cases. Here a rise in temperature from 273°C below zero to the temperature of the Sun can at any moment be achieved by exposure to the Sun, a simple and economical procedure.

For obtaining low temperatures glittering screens will be used as protection from the Sun's rays, and dark surface will irradiate heat into space. In this way temperatures down to 273°C below zero may be obtained.

This is what the most economical method of heating will be like: a chamber of the desired size and shape is completely enclosed within several walls that reflect sun-rays well. In this way heat is preserved within the chamber due to internal reflection, and the temperature remains at almost the same level, no matter how high it may have been originally. It is all like a vacuum flask, but more perfected thanks to the several walls and the absence of a material environment such as air.

The heat of the Sun enters the chamber through a small opening; a parabolic mirror behind the chamber (larger than the chamber itself) focuses the sun-rays in a small beam the size of the opening. Once inside, the rays radiate and heat the space inside the chamber to the temperature of

the Sun, no matter how small the mirror. But this is in ideal conditions with the full preservation of the heat, the opening no larger than a dot, and perfect mirrors. In practice none of these conditions can be ensured, and so the temperature will approach that of the Sun only if the mirror is many times larger than the chamber. Then its walls inevitably become heated a little and this impairs their reflecting power, and prevents the chamber being heated to the temperature of the Sun (5000° to 10000°C).

The Sun is reflected in the focus of the parabolic mirror; the smaller the mirror, the smaller the opening in the chamber, the higher the temperature within. On the other hand, the influx of heat is proportionate to the surface of the mirror. Assume the radius of the mirror as one metre. The reflection of the Sun will be in the focal point, half a metre away from the mirror. The angle of the solar reflection half a metre away will be about half a degree (this is the angle of the Sun from the Earth); the true size of the Sun's reflection (in mm) will be equal to the sine of half a degree multiplied by 500 mm, that is, about 4.3 mm. If the radius of curvature of the spherical mirror is P metres, the reflection of the Sun will be P times larger. So for a mirror of 100-m radius the diameter of the reflection will be 430 mm. Thus, the larger the radius of the mirror, the greater the reflection, the larger the opening in the chamber and the greater both the incoming and outgoing heat. We suppose all the mirrors to be similar, i.e., being equal to one and the same part of the complete spherical surface. Given this, it would seem that the temperature in the chamber should not depend on the size of the mirror. Actually, however, this is not quite the case: a larger mirror will give a higher temperature in the chamber, because the heat goes not only through the opening into the chamber but spreads all over its surface. There is another advantage of large mirrors: the speed at which the objects in the chamber become heated increases with the increase in the size of the mirror. In addition they pro-

duce more heat per time unit and if the heat is consumed by chemical processes inside the chamber, the processes take place more rapidly.

To simplify matters, assume that the mirror is round like a saucer. The mirror is part of a spherical surface. We join the centre of the imagined sphere to the edges of the mirror by a radius. The angle obtained cannot be more than 180° (a hemisphere). But this angle is almost useless as it focuses only a little more rays than does a mirror with an angle of 90°, or even 60°. So we shall take an angle of 60° for mirrors of all sizes. The width of such mirrors will be equal to the radius. Thus if the radius of a mirror is 100 m, its width will also be 100 m, and the size of the reflection, 430 mm (always 233 times less than the width of the mirror). If the chamber is a complete sphere the width of the mirror in practice should not be less than twice the diameter of the chamber. With a chamber of 1 m the mirror should be minimum 2 m. A quarter of its surface will be in the shadow thrown by the chamber, so it can be built in the shape of a ring. The lost quarter of the solar energy can be utilised by means of a biconvex lens or by a number of special mirrors. These should be placed in front of the chamber, nearer the Sun.

The mirrors may be immense for, even if they have a thin surface and are small in mass, they will not break or bend under their own weight because there is no gravity. To give them the required shape, a slow rotation can be imparted to them together with the chamber with which they constitute a single unit.

These units plus pressure and catalysers are employed for any chemical processes requiring a fixed temperature. The temperature can easily be controlled by changing the size of the mirrors and the system of screens. If a definite pressure is required as well, the opening has to be securely closed with a transparent shutter.

These chambers can be used to heat alloys for moulding, pressing and forging, to produce the desired shapes.

Now let us consider mechanical processing of cold, slightly heated, solid and semi-solid materials. We have described the simple devices, one square metre of the surface of which gives 1 hp. To obtain this energy mirrors, as well as chemical processes, can be used. So there is plenty of mechanical power. It can easily be converted into electric power if, for some reason, it connot be done by solar radiation directly. And it is a matter of common knowledge that high-potential electric power can produce a temperature above that of the Sun.

But will machines function without gravity? If foundations are necessary, these are available in the massive multi-chamber dwelling or in special premises. Now let us examine the work of a few machines in a gravity-free medium.

Coal and firewood will escape from the furnaces. If the furnaces are supplied with gratings, then small particles of coal will slip through. In addition, thin gratings will melt away or be burned up. The firewood and coal will not lie at the bottom of the hearth but will hover inside the furnace, filling it from bottom to top. This, however, is not so bad. There will be no natural draught, so an artificial is required. It is clear that coal, firewood, peat and similar fuels are impracticable in a gravity-free environment to say nothing of the absence of the necessary amount of atmospheric oxygen. But to start with we do not need ordinary fuels in space, and should the need ever arise for them, we could make use of coal dust, liquid fuel and artificial draught. But in general, in gravity-free environment the Sun does the heating and bodies are cooled by heat radiation.

We have seen that sometimes boilers with liquids will be used in motors. The liquids will not occupy the lower part of the vessel, because there is no below there; they will spread chaotically inside the boiler, mixed up with the vapours. But then liquid will escape together with the vapour, which is not what is wanted. Order can be estab-

lished in the boiler if it is rotated, or if the liquid is rotated within a stationary boiler by means of a wheel with blades. Both can be easily achieved where there is no gravity. The liquid will then spread along the boiler's equator and the vapour will occupy the axial area.

Now let us imagine a factory with wheels rotating, pulleys moving in all directions, shavings flying about, workers swarming like fish in water. If the whole of the factory building is rotating, gravity is formed and the conditions will be like those on the Earth except for a slight difference, depending on the amount of the artificial gravity. If there is no rotatory motion or if it is only slight, the gravity will be almost imperceptible. In this case there should be special boxes for all kinds of waste material, the air should be constantly filtered to free it from dust and particles flying about in it. Magnets will attract iron, steel and cast-iron shavings and dust.

But in some industrial processes (for instance, rolling and pressing) there are no waste materials, or they are harmless, and easily removed. No artificial gravity will be required there. Finally, when waste materials constitute a danger to the workers, a net or glass can be used for head-protection and some kind of pad—to protect the mouth. There should also be protective clothing. And even here, on the Earth, are we guaranteed against waste products—shavings and the like?

The workers and engineers flying among the machines and the finished products may get caught up in the wheels, levers and in other moving parts of the machinery and receive injuries. To prevent this, danger spots will be netted off. Then parts of the machinery can be remote-controlled. There will be nothing new in this—we have long been familiar with it on the Earth.

The part being processed, no matter how big, does not fall down, cave in or press on the workers; where there is no gravity it is easy to handle the part and carry it about. The workers, too, can work in any and every

position and place without being afraid they will fall (for instance, they can stand upside-down in relation to one another). All they need is some kind of support. A worker can always have support, if he attaches his feet or body to the object he is working on, or to his machine-tool. There is no praise high enough for the convenience of working in an environment devoid of gravity.

In performing all kinds of work, on the Earth it is not so much gravity as the inertia of massive bodies that is used. But in an environment without gravity a hammer can be as useful as on the Earth. The force of its blow depends not so much on the weight of the hammer as on the speed with which it is growing, which in turn depends on muscular effort and amplitude of the swing.

In machines the force of gravity is less utilised than in manual operations, and comparatively light presses can well supersede heavy hammers. Besides there is nothing to prevent man using some force to impart to some mass or other (in the ether) the velocity of falling objects on the Earth. The important thing is velocity, for it determines the force of the blow. It is easier to impart velocity to objects in a gravity-free environment than it is on the Earth. A blow due to gravity is always in one direction, downwards, but a blow due to velocity can be in any direction; that, too, is an advantage.

Thrown objects in a medium without gravity would seem to be more dangerous. On the Earth they fall to the ground and become harmless while in a gravity-free medium they will rush along a straight line until someone is hit. But, on the one hand, rapidly moving objects on the planets, like cannon-balls, fly through the air for a long time before they fall and come to rest, and, on the other hand, the objects wandering around in the ether dwellings, when they come up against walls, lose their velocity and come to a standstill. Such objects are more dangerous outside the dwellings, in space. But, firstly, these objects should not be let lose unless really necessary, and, secondly, they can

be guarded against, just as people guard themselves against bullets and cannon-balls on the Earth.

Mechanics in an environment free from gravity differ in no way from scientific mechanics; just leave out the gravity.

The Sun's gravitational pull at the distance of the Earth is not very strong: it is 1,800 times less than the Earth's gravity (the acceleration per second is 0.0055 m, or 5.5 mm). The effort lifting a weight to a height of one metre on the Earth will lift it here nearly two kilometres. But this does not mean that drawing close to, or moving away from the Sun at relatively low speeds is limited to kilometres. We are dealing with relative motions. A thrown object, in addition to the low relative velocity, also has planetary velocity relative to the Sun. Thanks to this last, and at its expense, the thrown object moves away from, or is drawn to the Sun over a distance of thousands of kilometres, despite its low relative velocity.

In our world environment, human beings and other equally small objects are mutually attracted, but this attraction is very weak. However, lead or platinum balls at very short distances from one another move like heavenly bodies. Their velocities have to be extremely low, otherwise they will scatter in different directions in straight lines.

This makes possible the practical solution in space ether of numerous extremely important problems which have not hitherto been solved by mathematicians. One problem concerns the paths of the movement of three interacting objects.

But what is inconvenient here is the slowness of the movement and the length of time of the observation. Thus, a comparatively small ball rotates round a comparatively large one made of the material with the greatest density known and at the closest possible distance, for a period of 2,500 seconds or 42 minutes. The time does not at all depend on the size of the larger ball: whether it is as large as the Sun or as small as a grain of small shot, the time of rotation is always 42 minutes.

For a practical solution of problems connected with forms of motion, the bodies are set at a distance from one another and the observation time is as much as several days or even months. It is this that makes it inconvenient. The absolute dimensions of the bodies may be infinitely small. Perhaps denser substances will be discovered or the attraction coefficient of small bodies will be found to be greater—then observations will take less time.

In order to obtain higher velocities, objects of great sizes have to be used.

An environment that is free from gravity offers the best conditions for determining mutual attraction and repulsion of bodies from different causes.

The bodies do not fall and have no weight but the laws of inertia are particularly easily observed here. The greater the mass of a body, the more difficult it is to impart motion to it. The greater the mass and the required velocity, the harder and longer has it to be pushed. And, inversely, if a moving body is to be stopped, the effort and time will be more, the greater its mass and velocity. The impact of a moving body is greater, the harder it is and the greater its mass, and, at the same time, the harder and more massive the body against which it strikes.

Although the oxygen atmosphere in the space dwellings will be one-tenth of that in our air, there, too, it will be found uneconomical to move quickly for a long time, as it involves the expenditure of much work. Outside the dwelling, however, in the void it will cost almost no effort: it will suffice to spend work once to acquire the desired velocity, which will remain constant if the movement is not away from the Sun. Even that, as we have seen, will have little effect over a distance of thousands of kilometres.

Travelling in the void will be possible either in spacesuits provided with breathing apparatus or in individual dwellings separated from the rest. The latter is more convenient as there will be more room, no need to wear clothes, the plants will travel as well and provide food,

water, oxygen and other necessities. Then the travelling can be done in large companies. The motion will be unnoticeable—only the dwellings left behind will seem to be moving. But conventionally their motion (to overcome the Sun's attraction) will be considered zero. It is as imperceptible as the motion of a planet to its inhabitants.

How will dangerous collision between the moving dwellings, shall we call them carriages or trains, be avoided? There will be several main travelling directions and one speed for each direction. The trains going in one direction will travel along one route so there can be no collisions. The routes of the different directions will lie at great distances from one another and the heavenly trains travelling at different velocities cannot collide.

The laws of levers, liquids and gases will not be complicated by their weight.

Gas disperses indefinitely until as a result of expansion and cooling it becomes dust consisting of solid particles that will not evaporate.

Liquids take the shape of a sphere or bubble; volatile liquids quickly freeze owing to evaporation, and the nonvolatile keep their spherical shape. The spheres may be broken into several smaller ones and vice versa. Adhesive liquids will stick to various objects, making queer shapes.

Sounds and other oscillations of all kinds propagate just as they do on the Earth, but there are no waves like those in the sea—for this there must be gravity. The barometer and pendulum clock do not function. Watches, however, go well. Spring and lever balances are useless as bodies have no weight and neither type is good for determining the mass. Mass is determined on a centrifugal machine, or on the balances in the state of artificial gravity. Force can be measured with a dynamometer or spring balances.

Magnetic, electrical and other forces operate more simply and clearly, because there is no gravity to complicate matters.

Man will quickly adapt himself to the absence of gravity but animals have too little reasoning powers and will suffer discomfort. Wingless insects will flounder about futilely in the air, but once on a wall, will run about without noticing the absence of gravity. Flying insects and birds will move about but not quite as they wish. As soon as they reach a wall they will cling to it with their claws. Neither the birds nor the large animals will be able to walk: at the first attempt, they will find they have lost contact with the wall and are in a gaseous medium. Cats and other similar creatures with movable internal organs will be able voluntarily to turn their bodies by at least 180°.

We have seen that man, too, can turn and move about with the aid of a fulcrum, for instance, a hat. He can turn even without one; to do so he will have to raise his hand and rotate it as if he were turning the handle of a machine. The circular movement of a hand, leg or other limb will make his body rotate. As soon as the man has ceased moving the limb his body will come to a rest, although he may find himself facing in the opposite direction.

We are not speaking of a liquid or gaseous medium in which any desired movement can be performed.

Man must at all costs overcome the Earth's gravity and have, in reserve, the space at least of the Solar System.

All kinds of danger lie in wait for him on the Earth. We do not mean the difficulties we all daily experience: mankind will soon do away with these. We are talking of disasters that can destroy the whole of mankind or a large part of it.

Take the dry land we now live on—how many times has it been flooded over and turned into the bed of an ocean! We cannot be sure that such phenomena always occur gradually. Earthquakes happen abruptly and destroy whole towns leaving under water vast stretches of land. There have been many major catastrophes although man has not witnessed them (if we leave aside the very doubtful Del-

uge). True, the greater a disaster the wider the range of its action, the less frequently it occurs. But we may yet live to see one.

For instance, a cloud of bolides, or a small planet a few dozen kilometres in diameter, could fall on the Earth, with such an impact that the solid, liquid or gaseous blast produced by it could wipe off the face of the Earth all traces of man and his buildings. The rise of temperature accompanying it could alone scorch or kill all living beings.

Imagine the same thing has happened to the space dwellings: an asteroid ten kilometres in diameter has pierced one of them. All it can destroy is 75 square kilometres of inhabited area, not 510,000,000 square kilometres as on the Earth. Of course, the path of the planet or asteroid is easier to follow in the ether, so that the dwellings may be temporarily removed from it; moving them about in space costs almost no effort. But can we move the Earth to make way for some heavenly body!?

A few words about aerolites. Large ones are as dangerous in the ether as they are on the Earth, but since they very seldom fall on our heads, roofs and buildings, and no one fears them, so also they strike no fear into anyone in space. From small aerolites, we are protected by the Earth's atmosphere in which they either become pulverised or burn out. In space, the dwelling itself can be a safeguard. If a tiny fragment of a meteor, a fraction of a milligram goes through a human being it will cause no serious harm. If it hits against a layer of quartz glass or steel, such a fragment would most likely get stuck in it. At the impact the fragment will melt and eventually evaporate. In the same way an infinitesimal part of the dwelling's surface will also melt and evaporate. The impact may make a tiny hole in the wall, but the molten fragment will fill in the crevice and even gas will be unable to escape through it.

In addition it has been proved over and over again that for an aerolite to hit a human being is highly improb-

able, and could happen on an average once in several thousands of years (supposing there were no atmosphere on the Earth).

The ultimate fate of the Earth—as of all other heavenly bodies—is an explosion from the accumulation of elastic matter inside it. The time will come when mankind will be faced with this sort of danger. How will mankind save itself if it has not mastered space within the Solar System?

And there is yet another danger—the cooling down and extinction of the Sun. Then man will have to escape from the Solar System, too. It will be much easier to escape from ethereal space than from the planetary prison where we and all we possess are chained down by gravity.

We are further compelled to take up the struggle against gravity, and for the utilisation of celestial space and all its wealth because of the overpopulation of our planet .

Numerous other terrible dangers await mankind on the Earth, all of which suggest that man should look for a way into the Cosmos.

We have said a great deal about the advantages of migration into space, but not all can be said or even imagined.

CHANGES IN RELATIVE WEIGHT*

MERCURY

We are off to Mercury, the planet closest to the Sun (though easily visible in tropical climates, in our country we see it very seldom); it is 2.5 times nearer to the Sun than the Earth is, and receives seven times more sunshine.

One or two hundred kilometres from the Moon, I looked down and saw, in its place, a golden bowl with circles and scars and occupying exactly one half of the sky. The other half was black, studded with stars, and adorned by the regal Sun.

As I shot further and further away in the same direction, this bowl—the Moon—occupied less and less of the sky, dwindling first into a plate, then a saucer, then into the ordinary flat Moon we are accustomed to seeing, and, finally, into a point, a tiny star (much the same picture as would be seen when moving away from the Earth).

I saw the Moon as this tiny star throughout my entire journey, the Earth meanwhile appearing also as a star 13 times brighter; when farthest away, near Mercury, it shone fainter than Venus. The constellations and Milky Way did not change their appearance or position either during the journey to Mercury, or throughout the entire planetary system including Neptune; and no wonder, as the entire planetary system appears as a spot compared with the interstellar distances; and wherever I went I was always near

* Excerpt from the manuscript.—*Ed.*

the Sun. Of course, in relation to the stars, I seemed always to be in one spot, though I travelled thousands of millions of kilometres.

Mercury almost always was aligned with the Earth (i. e., on one radius with the Earth and the Sun), in its most favourable opposition, and therefore this time I had about 100 million kilometres to cover. As I approached the planet, the temperature rose, and the Sun seemed to broaden. It was not the temperature of space that rose; since it did not become warm, as it had no substance (except for its infinitely rarefied cosmic ether, the conductor of light) and was absolutely transparent to heat. What did warm up was my own body, which from time to time I shielded with the aid of a screen. The screen also became warm, and warmed me with its dark thermal rays, but however, when I was far enough away, the heat was by no means very intense. Using the screen to shield myself from the Sun's scorching rays, I had an excellent view of the stars studding the gloomy background of black, and among them my destination—the shining star Mercury, to which I had drawn much nearer.

Now it was clearly beginning to look like a tiny, horned Moon; it became rounded and showed me all its phases as I circled around it. The baby Moon became larger and larger growing before my eyes in accordance with the speed of my journey towards it. It became as large as the Moon as seen from the Earth; as large as the Earth when observed from the Moon; it changed into a plate, and finally into an enormous silver bowl taking up half the sky. Clouds and mountains, the planet's watery and solid areas came in sight. At last, I reached Mercury itself.

This planet, which has the density of iron (the Earth has a mean density, which is equivalent to that of fluorspar, i.e., 5.5) is as many times closer than the Earth, i.e., 2.5 times. The duration of the day is the same. The Sun is seen as a body that is seven times larger and brighter and it gives seven times more warmth. Objects weigh half

of what they weigh on the Earth. A freely falling body drops no more than 2.5 metres in the first second. The mean temperature is around several hundred degrees centigrade (on the basis of Stefan's law and presuming conditions identical with those on the Earth, the temperature was estimated to be 176°C). Naturally, all organic bodies transported from the Earth to this planet die and disintegrate. But do not imagine that this means there is no life there! On the contrary, it is teeming with life. The population is a hundred times denser, more evenly distributed and far better educated than on the Earth. What is the explanation?

What prevents a locomotive from working when the surrounding temperature is 100°C? What is it that makes it impossible to light a fire, that prevents coal from burning and many other chemical processes from taking place in the same conditions? What, in general, is it that prevents the most intricate of machines and even organisms from functioning, when they are made of refractory substances and liquids that do not boil at this temperature? I do not know the substances from which Mercury's inhabitants are made, and even less do I know what compounds are formed by these substances; all I do know is that animal tissues resist Mercury's high temperature just as successfully as our bodies stand up to a heat of 20°C. The temperature of their bodies and especially of large Mercurian animals is, obviously, still higher than the surrounding temperature, owing to the processes of digestion, breathing, thinking, etc., going on inside them. They could easily fry our veal or cook soup in the palms of their hands. At the height of my curiosity, I several times forgot this and burned myself when I touched their soft and tender skin. The same happened to the Mercurians when they touched my hands and face, only in this case the burns they suffered were due to the relatively excessive cold temperature of my body.

Mercury has no bodies of water; the water, with other gases and vapours, forms the atmosphere. It is only in its top colder strata that at night, the circumstances being

favourable, clouds and mists form which resolve themselves into torrents of hot rain which rarely reaches the ground. Even if small drops of hot rain reach the ground, they are at once transformed into vapour, refreshing Mercurians and soil alike.

They have a very well-developed industry and civilisation but complain that the dense atmosphere prevents their locomotives from moving rapidly. They also complain of the high gravity, of the impossibility of making contact with other worlds, of the overpopulation, due to which the people have nowhere to spread to and long since set a limit on the reproduction of their kind.

Rational beings are dissatisfied with everything! Imagine them complaining about gravity! Is this a merit or a fault? Sometimes—a merit, if dissatisfaction with the present state of affairs takes the form of aspiring towards an ideal, to what is finest, without violating love towards one's closest friends.

So what have the Mercurians to grumble about, when gravity on their planet is only half what it is on the Earth. I felt fine here (how I tolerated the infernal heat is my own business), ran with ease, and leapt three times as high and as far! Their trains move ten times faster than trains on the Earth. They have none of the confusions or the international strife from which our poor Earth suffers; nor is there that gulf between different types of inhabitants, which makes one the slave of the other. Incidentally, it is indeed crowded on the planet, because of the population and its small surface area. Then, there are very few seas of some dense liquids that I know nothing about. All the dry ground, up to the poles, is inhabited, so that their populated area is nearly the size of that on the Earth, the total surface area of which is seven times larger.

They have evolved some eccentric projects which the prudent majority have no faith in, though they condescendingly tolerate them. One such project, for instance, is to create rings similar to those of Saturn, by causing masses

to revolve rapidly round the planet outside its atmosphere—and so to extend their territory!! To start off these rings, it is necessary for the surface velocity to be as much as two kilometres a second; meanwhile, their fastest trains (which are streamlined like airships to cut through the atmosphere) do maximum 300 metres a second, which is by no means fast enough. Incidentally, the designers of these projects suggest various methods for reducing friction and increasing velocity so as to offset the relative gravitational attraction. They also propose methods of providing comfortable living conditions ... (here two pages are missing from the manuscript.—*Ed.*)

... and sea routes and use them even more than air routes, especially for transporting cheap cargoes. Aircraft (which are birdlike and have wings) are also extensively employed, but by the wealthy people or the government, because for the average Mercurian this means of transportation (which happens to be the fastest) is beyond his means. The Venusians, true, have not attained Mercury's civilisation, yet none of them walk around with their heads in the clouds, inventing the impracticable projects for which the Mercurians have such a weakness. Let me repeat that our good neighbour is closer to the Earth even in the figurative sense, because were some addle-pated eccentric to suggest expanding territory by means of rings circling the planet as Saturn's rings do, he would, without a moment's waste of time, be clapped into a mad-house, of course, out of the most humane motives in the world!

So farewell Venus, likeness of the Earth, magnificent adornment of its evening and morning heavens!

MARS

Mars is twice the distance away from the Sun that Venus is and is 1.5 times further away than the Earth. The amount of warmth received by about 3 acres of soil on Mars is only half of what the same area on the Earth gets in simi-

lar conditions. Naturally, the mean temperature of Mars must be much lower than the Earth's and this is indeed so. Its mean temperature is 32°C below zero (the maximum being 83°C above). However, do not think that the planet's absolute temperature, from 273°C below (absolute zero) is in proportion to the intensity of solar light and heat, or to the visible surface of our luminary. Because then, presuming the Earth's absolute temperature to be some 300 degrees, we would find, roughly, that it should be 2100° or 1900°C for Mercury, 600° or 300°C for Venus, 130° or 130°C below zero for Mars, etc. As we have partly seen, there is nothing of the sort. The temperature is far more moderate and, for that matter, Mars does not have and cannot have such lasting cold. Indeed, even on the Earth in winter the Sun shines down with an intensity that is one-fifteenth greater, because it is nearer to the Earth at the time. If we were to allow the earlier argument, then the average temperature of the Earth in winter would rise by some 18°C. Is this ever observed? Is there ever an average increase of even 1°C?

In times beyond recall when the Sun was still brighter and bigger and when Mars itself and its surface were still hot, the planet's waters occupied depressions, as our terrestrial seas do. It was here that they became petrified, forming the solid part of the crust, when the times changed and the temperature dropped.

However, in Mars' equatorial zones the Sun's rays, that were shed upon this ice, melted it a little at the top, making it polished and transforming it into vapours. The vapours, carried away into the atmosphere in negligible quantities, gave rise to the snow clouds, and snow was precipitated at night in the polar regions of the planet, to form a sparkling layer; sometimes the planet was simply covered with white hoarfrost [as] at the terrestrial poles. It was precipitated on to the ground directly from the atmosphere, after coming into contact with the extremely cold regions of the planet.

There are relatively few of these petrified seas and tributaries—Martian "canals".

Thus from the surface, the planet represents one solid mass, if we disregard the slightly damp and extremely muddy ice, which gives rise to the miserable little streamlets, immediately freezing and becoming covered with white hoarfrost as soon as the Sun sets. At night the entire planet is covered with it, but terrestrial astronomers cannot see the planet's night-bound part; meanwhile, on the sunlit side, except for the polar areas, it melts soon after sunrise, with the result that the ice and dry land cease to look like snow and appear as seas or ordinary dry ground.

The Martians utilise the glaciers and oceans of ice lying in horizontal plane as a means of communication.

The planet is much smaller than the Earth, but a little larger than Mercury. Gravity on it is two and a half times less than that on the Earth. Objects weigh there two-fifths of what they do on the Earth. The days are as long (a controversial issue as yet), but the year is twice as long. There are two moons to light up the sky at night. They are both small and glow faintly and are important only because they are near the planet. The closest, Phobos, glows with a light that is 8 times fainter than our own Moon. Its visible diameter is half (of our Moon). On the other hand, Phobos traces its course across the heavens very quickly, faster than the Sun, which is why every 12 hours *it sets in the east and rises in the west*. The other satellite moves ordinarily but slowly, so that it rises above the horizon only once every five days (approximately).

The inhabitants, i.e., the Martians, are most charming, but they were very cautious when they were with me, fearing to get scorched. While Mercurians and Venusians used me as a refrigerator, here I was employed as a well-stoked fire. They made a great fuss of me; indeed, warmth went with me into every home. I am speaking, obviously, about winter in moderate climes. In the summer, despite the frost, which is seldom with us, "heat" made them gasp,

and sweat out peculiar and extremely volatile liquids. It was during this time of the year, so unfavourable to me, that I decided to slip away from them in as delicate a manner as I could.

VESTA

Beyond Mars lies that belt of asteroids thought to be fragments of the big planet, which according to Baudot's law, had once existed between the orbits of Mars and Jupiter. Incidentally there are many reasons why I personally think this hypothesis very unlikely.

So let us bid farewell to Mars and its satellites and travel beyond its orbit. At once we encounter beyond it a host of minor planetoids, but I shall not speak about them for the time being. Rather let us head straight for the largest of them, to their queen—Vesta.

It is $2^1/_3$ times farther from the Sun, than is the Earth and gets 5.5 times less sunshine.

The diameter of the Sun itself seems to be a bit more than twice as narrow and its surface 5 times as small as when observed from the Earth. It gives out as many times less heat and light.

In spite of the low mean temperature, the inhabitants of this asteroid are like the selenites, but are composed of materials that do not freeze and are elastic. They do not suffer from the cold at all, and sing their way through life, not literally, of course, for since there is no atmosphere, they can hardly go in for vocal exercises.

They have no plants or animals except at their scientific establishments, where they are treated with every care and attention, kept in special conditions and are used for experiments and research purposes.

The rational population with their transparent skin that lets through light, but does not let matter escape, live to a ripe old age, but progeny are seldom born. The young generation is brought up in special, completely enclosed nurseries, which while they let in light, do not let in gases

and liquids. In short, during their early life Vestians develop and grow in roughly the same way as the inhabitants of the Earth or the Moon, the only difference being that their environment is purely artificial and that sunlight is a very important part of their diet.

As soon as they reach normal height, and their skin hardens, while the sudoriferous glands, lungs, and other organs unnecessary in a void, become sealed up or atrophied, they emerge into freedom with their emerald-green wings, like butterflies from the chrysalis. Throughout the whole of their subsequent happy life, they change only internally. Their thoughts change, gradually become perfected and arrive at the truth, while inside their bodies, which are outwardly constant in appearance, the eternal plant-and-animal cycle takes place, as described earlier (for the Moon).

On Vesta gravity is 30 times less than on the Earth, because the planet itself is very small and compared with our globe is like a grain of millet (2 mm) compared with an apple (60 mm). That is why here gases are stored exclusively in sealed containers or in a chemical bond with non-volatile liquids and solid substances. The small gravity is unable to hold back the headlong movement of the gas particles, which are completely dispersed in the boundless reaches of space leaving nothing round the planet; meanwhile on the Moon these particles accumulate in its deep crevasses which serve as natural nurseries for growing generations.

Owing to the small gravitational pull, a pood weighs hardly as much as a pound. A human being seems to weigh no more than a chicken. The inhabitants carry their green wings as though they were eider-down; the relatively large surface of the wings provides them with plenty of solar energy, though the Sun's rays are not at all strong. This energy makes their movements extremely easy, and their thoughts, on the other hand, most profound. Incidentally, the ease with which they move is due to the light gravity.

Do you know that when I found myself here I thought there was no gravity at all, I felt so light. And here, the expression "floating on air" is justified. If anyone weighed me, a husky chap turning the scales at over 70 kilograms, they would have found me registering not more than $5^1/_3$ pounds on a spring balance. After Mars, where objects weigh 15 times more, this seemed to me really very light! I could jump up vertically 40 metres, the height of a pretty high belfry which, unfortunately, do not exist there. I could take in my stride a ditch 170 metres wide and even more if I gave myself a running start. Even without an effort, I achieved astounding results.

Since the inhabitants find it so easy to move about and encounter no air resistance when running, they have long been thinking seriously of how to extend their possessions, by using speed to strike out into space or by forming moving rings and the like around the planet. Listening to their arguments, I ceased to be amazed any longer at the ideas advocated also by the Mercurians. Indeed, if not now, then probably in the near future they would achieve their aims.

Everything hinged on the insignificant gravitational attraction. One of our terrestrial cannon-balls, fired from the Vesta, would, as it were, break through the "crust" of its gravitational pull, and escape from the planet forever to become a satellite of the Sun, a newly formed planet. If. . . (several words are omitted here—*Ed.*) on the Sun it would move away from it eternally and always in the same direction.

If Mercurian trains, which run at 300 m/sec were placed on Vesta's smooth equatorial route, then owing to the centrifugal force they would not only lose their weight entirely or, in other words, would not only cease to press down on the rails, but would even fly up into the surrounding space, which the inhabitants of this apparently insignificant tiny planet so long to conquer. Such fast trains would

be all the more possible as the friction is 30 times less, while the atmosphere is splendidly "conspicuous by its absense"; and the gases the inhabitants require for the younger generation are obtained not from the atmosphere, but from the solid ground; the Vestians decompose chemical ores and other oxides and thus, with the Sun's help, get oxygen, nitrogen, etc.; incidentally they store gases mostly in a weak-bond combination with other substances; these compounds, which are usually solid or liquid, relinquish their gas to anyone who needs it, or for any required purpose, as soon as they are slightly agitated (for instance, by heat).

So you see that Vestian trains stand no comparison, as far as speed is concerned, with those on Mercury; however, the speeds they attain are quite enough to reduce their weight appreciably, almost by half.

How astonished the Mercurians would be if told that on Vesta their trains would attain their "lofty" aim of exploiting and colonising space going to waste and the escaping energy of the Sun's rays! I think that after hearing about it, they would redouble their efforts to achieve success. Probably even the Martians, who have never even dreamed of anything of the sort, would also shake themselves up a bit!

But the question is: how do the Vestians set their mechanisms, trains, for instance, in motion? After all, it is not by using their muscles, surely? But, of course, they have solar engines, like all rational beings living in gasless space. These devices are, approximately, of the following design. Imagine a slender air-tight vessel that can change its volume much like a concertina or a pair of bellows. Even we, on Earth, have made similar cylinders only made of metal, with the idea of replacing steam-engine cylinders with them. They were air-tight and resembled a Chinese lantern, folding up into a thin flat circle; this vessel contained a quantity of some suitable gas or steam which first expanded to move the walls of the container apart, when

its black half was exposed to the Sun, and then became compressed, when placed in the shade behind a screen, and it lost more warmth than it received. So, in ordinary circumstances the walls of the container would either move apart or come together much like a concertina in the hands of the performer; this could serve as a source of a fairly considerable amount of mechanical work. It would already perform work simply by alternately turning first its dark, and then its shiny side towards the light by the force of inertia (after the initial push).

I have described the simplest type of the least bulky solar motors. There were also other types of motors; in these the gas or liquid, which was heated either directly by the Sun's rays or by means of reflectors (i.e., mirrors), was forced from one container into another placed in the shade, and therefore extremely cold; in this process the gas or steam performed work, as it passed through a steam engine. These machines are more intricate and bulkier, but they are more economical, because from the given sunlit area they derived a greater amount of work. There are still more intricate systems. None of them ever loses a single drop of liquid or gas; it is sometimes lost by pure accident, but extremely little.

Judge for yourself how powerful these motors can be from the following: theoretically the work performed by the Sun's rays falling perpendicularly on one square metre from a distance equal to that between the Sun and the Earth—if all the energy is transferred by machines without any loss—will be 2,120 kg m, which is about 1.5 hp per square arshin (2.13 m), or the equivalent of 15 husky labourers working round the clock. But since the intensity of the Sun's rays at the distance of Vesta from the Sun is five times as weak, and since motors can convert not more than a third of the radiant energy into mechanical work, a square arshin of motor space will be equivalent to the work of one husky labourer working continuously (0.1 hp, or the work done by a man steadily climbing a

staircase at a rate of a quarter of an arshin every two seconds).

Strictly speaking, the Vesta inhabitants expend very little muscular energy due to low gravity, which means that their muscles are weak. All work is done by the motors described, which operate machine-tools, used for a variety of purposes and varying in complexity.

If the inhabitants of Vesta were put on our clumsy Earth, they would immediately be crushed to death because of gravity, and the same would happen to us if we were put on the Sun, where gravity is almost as many times greater than that on the Earth as this latter is greater than gravity on Vesta. The blood vessels of the slim-legged Vestians would burst and then, of course, they would be too weak to carry themselves; their wings would become flaccid and droop feebly and their bodies would drop to the ground and break into pieces; it would be as though an overburdening load had been heaped on to them.

But, after the horrible fetters of terrestrial gravity, and not having been spoiled by any tenderness from it, I felt "on top of my form" here, and astonished my hosts by performing wondrous acrobatic stunts.

If I had been put back in my native land, I would have felt terribly disappointed there and would have felt like an earth-worm.

Vesta's eccentricity is small and so its temperature is practically constant all round the year. It has the same diurnal period of rotation as the Earth; consequently, the velocity of its equatorial points is not so small as to make it possible conveniently to follow the Sun and turn evening into morning and vice versa, or, in short, to control the times of the day and night as one could on the Moon. The highest velocity capable apparently of halting the Sun in its diurnal course and perpetuating day or night is roughly 15 m/sec, or 1,333 km in 24 hours. The Vestians can run at that speed, but it is a strain they would prefer not to put upon themselves. On the other hand, in their trains which

travel much faster, miracles are encountered at every step. For instance, you may get up in the early morning, board a train and be in a great hurry to set off; but alackaday! the joyful Sun, which has only just risen, begins to set two or three hours later.... Is there anything more fascinating than hoping to enjoy the freshness of the morning and finding yourself travelling by night!!

Then it sometimes happens like this if you are travelling in the opposite direction: you board a train in the evening, hoping to admire the sunset, read a little, perhaps doze off in the stillness of the night, and suddenly find that instead of setting, the capricious Sun is rising higher and higher in the sky; you are in despair, the Sun prevents you from sleeping and upsets all your innocent plans. But the Sun is inexorable; noon comes followed by the evening; the time lost is, as it were, retrieved; the Sun sets; you rub your eyes, unable to believe your senses; you grasp your head, aching from lack of sleep, and completely disappointed you sleep the slumber of the dead.

But imagine the horror of the traveller who set out westwards one night on a trip round the equator at a speed of 54 km/h and saw the sky in petrified immobility. One hundred, two hundred, even a thousand hours pass and not a star wanes nor does the Sun rise; there is no daybreak, nor will there be. Bear in mind that the daybreak we are accustomed to, the rosy break of day produced by the Earth's atmosphere, does not exist on Vesta; there is a special kind of daybreak, partly the zodiacal light and partly the alternating reflection and glow of the elevated and sunlit regions of the planet. It is just as ghastly when you set off at noon and the stationary Sun beats down relentlessly, unceasingly.... One can well go mad....

The planet is extremely densely populated. The population is a little less than that of the Earth, inspite of the diameter being 30 times smaller and the surface area 900 times less; consequently the surface area per head of the population is 370 sq m.

As for its volume you can judge this from the fact that from the total mass of the Earth 27,000 little spheres the size of Vesta could be made!

Mountains, in general, are smoothed down to provide convenient routes of communication; however, their chronicles provide data about mountains 100 kilometres high; so it was not possible to say of this planet that, even from some distance away, it was reminiscent of a finely polished ball or globe. Indeed, these 100-kilometre elevations had covered only a quarter of the planet's diameter and had made it more resemble a rock or a piece of shrapnel than a sphere. Calculations show that the relative elevations of a planet, the conditions being the same, are proportional to the square of the diminution of its diameter. The diameter of Vesta is 30 times smaller than that of the Earth, relatively the biggest mountains on Vesta could be only 900 times taller; the height of the mountains of the Earth is not more than 1/1,200 of its diameter, and consequently the height of the mountains on Vesta will be 900/1,200 or three-quarters of its diameter.

Incidentally, the elevations on these minor planets may be still greater, owing to the diminution with distance of their gravity.

CERES AND PALLAS

However, let us leave this charming, hospitable planet and its highly erudite inhabitants, who dream at some time in the future of breaking out of the clutches of the gravity of their planet and embarking upon a mighty exodus into the infinite reaches of space, outside the miserable surface of their planet, and so extend their control over nature; let us part with these kind-hearted dreamers and fly onwards.

While roaming absent-mindedly among the asteroids, I wondered where all these creatures came from. Their being on the Moon was comprehensible. The Moon had once had

an atmosphere, and the gradual rarefaction of the atmosphere over tens of thousands of years could have adapted their bodies so much that they were able to dispense with an atmosphere. But what was the origin of the inhabitants of Vesta, where, because of its small size, there could obviously never have been any gases at all, since their particles have a velocity of a cannon-ball and like the latter should have overcome the feeble gravitational attraction and have dispersed. I wished I had had a serious talk with the Vestians about the origin of their ancestors. But I had no desire to return, particularly as the distant horizons were such an enticement.

Ceres and Pallas come next in size after Vesta, the largest of all the planetoids. Their mean distances from the Sun differed very little, but their orbits did not lie in one plane, they obviously could not intersect, otherwise they would certainly collide at any rate several thousand years hence.

The mean distance between the Sun and these asteroids is about three times (2.76 and 2.77) greater than the distance between it and the Earth; the Sun seems as many times smaller in diameter when observed from them; the strength of the Sun's light, heat and gravity is only one-eighth what it is on the Earth.

Ceres is slightly closer to the Sun than Pallas and is a little smaller than Vesta; to be exact it is only 63 kilometres smaller across than Vesta, which means that it is smaller by one-sixth, or one-seventh; however, because Pallas possesses an eccentricity that is incomparably greater, the apparent diameter of the Sun fluctuates greatly in its annual motion (i.e., during one full revolution around the luminary) from 1 to 1.7, while the intensity of the Sun's warmth ranges from 1 to 3. Moreover, this planet was right on my route, while Ceres was at the opposite end of the orbit, and I would have had to go nearly 1,000 million kilometres out of my way to visit it. Pallas and Vesta greatly differ in size; Pallas has a diameter of only 255 km,

about half as long as Vesta, which is why on Pallas objects weigh 52 times less than they do on the Earth.

Because of these considerations I hastened on to Pallas but even before I arrived, I saw with the naked eye that it was enveloped in an atmosphere that seemed to be of a tremendous height. At once I recollected the observations of Schröter who had also seen that Ceres and Pallas had atmospheres and who had established that they each reached to three times the height of the diameter of the respective planet.

As far as Pallas was concerned, this had proved true and I began to regret that I was unable to verify the astronomer's observation with regard to Ceres.

The atmosphere was extremely transparent, not at all distorting or refracting the rays from the stars that passed through it; this seemed odd as, in general, did the existence of this "extremely high" atmosphere.

But a moment later I had drawn so close that I clearly realised my mistake. It was not an atmosphere at all, but simply a ring, like Saturn's; only it reached down to the very surface of the planet; after flying off at a tangent and viewing it from the side, I realised still more clearly that I had been mistaken; indeed, the ring appeared as an ellipse, even as a thread, which could not be the case with an atmosphere; we know that in the course of its revolution round the Sun, i.e., in the course of 30 Earth's years, Saturn's ring also twice appears sideways in the form of a thread, because twice its plane falls in with the angle of vision of the terrestrial astronomer, or, in other words, is aligned with the Earth's orbit.

I found why Pallas' ring was transparent as soon as I entered it. I saw that it consisted of a vast number of bodies circling round the planet. These were the natives of Pallas, their homes, engines, factories and various apparatuses. Arranged freely, so as not to rob each other of the Sun's rays, they let through chinks of light, just as latticework does. From a distance the separate objects were not

visible; all that could be seen was the transparent totality of them producing an illusion of gas or of a rapidly revolving wheel. We should note in passing that some of Saturn's rings are also transparent, but so far we do not know why.

I rapidly flew past the dwellings of the legion of colonists, without really looking at anything properly, and set foot on the *terra firma* of Pallas itself.

I felt still lighter than on Vesta; I weighed myself on a terrestrial spring balance, and found I was 3 pounds. I could have walked barefoot along a flinty path strewn with sharp rocks, without harming myself; I could have flung myself down on the rock as calmly as on the softest eiderdown. I jumped twice as high and twice as far as on Vesta, providing the relatively puny inhabitants with the somewhat comical spectacle of a jumping flea, which, incidentally, amused them very much. They applauded every jump I made, which lasted half a minute or more, because I went up very high. While off the ground I managed to blow my nose, ask the time of day and even meditate for a while. Every time I required a "bird's eye view" of their structures, all their variety of buildings, their railways and so on, I leaped up and "from the highest point of vision " obtained a general picture of the things I wanted to see, and having shot up vertically some 60 metres, I hung suspended there for a while only to find myself, after a few seconds, accelerating to the ground again.

I shall not describe the natives, as they were surprisingly like the Vestians; the minor differences between them now elude me in the way that the differences between butterflies of the same species are forgotten. But I should mention that their bodies, which had emerald-green wings, were as elegant as precious malachite vases, that their eyes sparkled like diamonds. Let me repeat that they fed on sunshine, like plants, and were as innocent as flowers; when I called them Sun-children, they were puzzled and said: "The Sun itself is a drop of wisdom."

I was most curious about their "rings" and life on them,

outside the planet itself; I wanted to know how they had managed to create these artificial rings, and how they had hit upon the idea.

I conversed with them by means of pictures, drawings and gestures, which they also employed, but chiefly with the aid of the natural pictures, drawn in the differently coloured subcutaneous liquids on their transparent chests; it was obvious that their brains and thoughts were linked by vasomotor (vascular motor) nerves, with the ebb and flow of these liquids. This was the universal prime "language", which I encountered wherever an atmosphere and aerial sound waves were absent. This language is the same everywhere, because it depicts the real nature of objects and phenomena, by composing some likeness of them; the speech organs of the natives were very intricate, I could not keep abreast of them in the speed and accuracy with which they conveyed their ideas; I understood them better than they understood me; for, who, indeed, would fail to grasp the meaning of the wonderful paintings that flashed out on their chests, only to disappear and give way to pictures that were still more understandable or that were the second part of the story given in the first set. You can see something of the sort in the moving, tinted light images of the camera-obscura (or photographic apparatus).*

The chest pictures of the Pallasians flashed past just as quickly as their thoughts and ideas; their eyes served them as ears.

ON THE RINGS OF PALLAS

Having seen Pallas itself, we turned to what was most remarkable about it—its disk, or circle, right in the centre of which was the planet itself.

It was much easier for the inhabitants of Pallas to realise the dreams of the Vestians: to colonise surrounding space. Indeed, it is not so difficult to combat gravity there; a

* There was no cinema at the time I wrote this.

speed of 200 m/sec is enough for a body to escape from the planet forever and become a satellite of the Sun, or in other words, an independent planet. It is enough for a train to work up a speed of 141 m/sec, to shed weight and to escape into the surrounding void; such a train, doing 508 kilometres an hour, moves only 4 times faster than the fastest trains on the Earth. This, and even greater speed is quite attainable here because objects weigh fifty-two times less than they do on the Earth; friction of every kind is also as many times less. Hence speed, in the case of an identical amount of energy being expended, can be safely increased (in relation to the speed of terrestrial trains) fourfold. Taking into further consideration the absence of drag and the perfection of the railways and machinery of the Pallasians, it can be increased five- or even tenfold, but that would be superfluous, as a fourfold acceleration is quite adequate.

Only do not imagine that you would see right on the planet's equator a train travelling at 500 kilometres an hour and covering the distance round it in only one hour and 35 minutes! No, the first train, standing or travelling on the actual surface of the planet itself moves at 14 m/sec (50 kilometres an hour). It winds round the planet in an endless circle moving round it in much the same way as a worm round a nut. The second train, which is like the first, but which runs on top of it, as if on a moving platform with moving rails, has the same speed in relation to the first; however in relation to the planet itself it possesses a speed that is twice as great, or in other words, it travels at about 100 kilometres an hour, or about 28 m/sec.

The third train moves with the same velocity and in the same direction; in relation to the second it travels at 14 m/sec, while in relation to the planet it possesses a speed that is three times as great (150 kilometres an hour). In this fashion each train higher up travels at 50 kilometres an hour faster than the one beneath it, but the velocity of each train in relation to the planet depends on its position;

for example, a fifth-level train will already travel at 250 kilometres an hour. The highest or tenth train, moving on top of the ninth, which, like all the other trains, is an endless circle with platform and rails, already travels at 141 m/sec; owing to the centrifugal force, objects inside weigh nothing and the train itself weighs nothing; it barely touches the rails. The next or eleventh circle will hang suspended in space without the slightest support and without any contact with the tenth, even though the speeds of the eleventh and all succeeding trains, far from increasing in relation to the planet itself, even decrease a little; the speed of the tenth train, which is 508 kilometres an hour, is the peak velocity of the entire multi-tiered ring or circle stretching up to a height of 800 km; further up the speed of the ring continually diminishes, but extremely slowly, consequently the difference in the speed of the two neighbouring trains is imperceptible, meaning that they move at an almost identical speed; the fringe of the "circle", the top train, travels at only 53 m/sec, which means that its speed is a little over one-third of the highest speed.

After this brief description of the essence of the "multi-tiered" trains and the secret of the existence and origin of the rings of Pallas, let us climb in to the first train, which is done extremely easily; we need only to run beside it. After all, 50 km an hour is nothing on a planet where objects weigh 52 times less, and air resistance, so perceptible on the Earth at such a speed, is quite absent. Having done that, we need only stretch out an arm as we run and grasp the bar, and we are on board; the entire manoeuvre is identical with the one used when jumping on a moving horse-drawn tram.

Here (on the first train) gravity is less than on the planet, though the difference is hardly felt; but it can easily be detected by means of the spring balance which you have taken along. It can also be spotted by observing the slower swing of the pendulum of the clock on the wall; to see

that you need only compare the time it shows with that of your pocket watch, whose mechanism does not depend on weight, but merely on the elasticity of the steel spring (hair spring). The diminution of gravity, in general, on the first train is not noticeable and does not strike the eye after all we have experienced in this respect; but it progressively increases from train to train. If we take the diminution of gravity on the first ring as the unit, on the second it will be four times as much, on the third—9 times, on the fourth—16 times, on the tenth—100 times, and on all subsequent trains—also 100 times as much.

From the first train we make our way in the same manner as before to the second; let us note, in passing, that we can use for the purpose the special devices which transfer you imperceptibly, and without effort, to any of the trains; however, I shall not tire your imagination describing them; most of the natives use them.

Once transferred to the fastest or tenth train, which is not very far away from the surface of the Pallas, some 22 metres or so, we find that gravity apparently disappears altogether; the pendulum stops swinging, weights no longer pull at the spring balance but register zero, and bodies do not fall down. I hung suspended in the middle of the carriage like a fish in water or a bird in the air, but, naturally, without my making any effort. My notions of above and below were confused in my mind and depended on the direction I took; above meant what was overhead and below meant what was beneath my feet, but as I did not fall down, my sensations were quite confused. I had to turn with my feet towards the ceiling of the carriage and everything in it, or rather in my brain, turned "upside down"; the floor of the carriage seemed to be the ceiling, and the ceiling—the floor, and it was difficult for me to convince myself that the carriage had not overturned. I did not feel its motion, because it was travelling extremely smoothly like a boat in water; but I am unable to explain how they achieved this. When I looked out of the window I saw the

planet itself receding in a direction opposite to my own, my movement was imperceptible to me, and every one and a half hours the Sun rose and those regions of the planet, which I had already seen before, came into sight again.

The slightest push was enough to send one flying inside or outside the carriage in any desired direction; I had merely to sneeze, yawn, or cough, for my body, which had so far been immobile and had been in contact, without pressure, with other objects, to speed forward for quite a while along a straight line. Together with this, since a rotational motion is, for the most part, added to the rectilinear motion, it seems to you that the planet with its train and the heavenly firmament with its stars and Sun are revolving round you.

With a gentle push against the wall of the carriage, I found myself shooting towards the opposite door but my fear made me clutch at the bar-handle on the steps outside; I clung on for some time, peering around me and slowly becoming calm again. No! The idea of shooting away from this ring terrified me. So I tied myself to the bar with a long piece of thin rope; then very gently I pushed myself away from it and flew a few seconds in a perfectly straight line; only the rope kept me from promenading further, and God alone knows, where I would have gone. The rope became taut and jerked me back so that I landed safe and sound at the side of the carriage. I was bounced off it again, this time involuntarily like a ball, for it had not been my intention to repeat the experiment. I again flew the entire length of the rope only this time slowly and remained almost completely immobile.

Beneath me the planet raced by, but I did not fall on to it, despite its gravitational pull; there unfolded before me glimpses of life on the planet, the various buildings, the wonderful palatial dwellings and the wreathing crowds of Pallas' dense population. Many of them boarded the trains, changing from one to another; others dropped down to the planet. My train and the rings higher up seemed

stationary, while those lower down seemed to dash along with the planet, running faster the closer they were to it; but actually, the reverse was the case.

The upper rings teemed with life and seemed like a miracle suspended in space; only some parts touched one another, leaving large gaps in between.

I pulled at the rope and the impetus returned me to the carriage; to ascend from it a dozen kilometres or so, a jump was enough; in this way having remoted the rope, I found myself on the top rings; after flying a fair distance and stopping outside one of the rings I took another jump and again flew several kilometres without any effort.

The area of the entire disk is 48 times greater than the surface area of the planet in its equatorial cross-section. Thus, taking into consideration the fact that the plane is not always perpendicular to the Sun's rays, we find that the inhabitants of Pallas were receiving 20 times more warmth and light than they had a right to, according to the size of their planet. Its diameter was only a seventh of the ring's width; this means that the ring was relatively larger than Saturn's.

None of the objects released carefully, without a push, on the rings above the 10th, ever fall anywhere. But if pushed, they fly (in relation to the rings), for a fair time in a straight line and smoothly in the direction of the push. It is possible even to shove an object towards the planet, but that would be dangerous as it would collide headlong with the first object to come its way. Anything may be thrown or sent in other directions. It will move upwards, downwards, or sideways, indifferently and quite freely, though given time it will nevertheless return to the rings. From this it is evident that the motion is curvilinear and not quite smooth (even in relation to the rings). However, over a distance of several kilometres and in the course of minutes, even hours, it differs in no way from the motion of objects in an environment having no gravity. Along the entire 800 kilometres upwards from Pallas, the ring is a

relatively gravity-free environment, provided we disregard the negligible force of attraction it itself has; however even this is practically absent in the gaps between the rings (the attraction of the lower rings is cancelled out by the attraction of the upper ones). This relatively gravity-free space does not differ in beneficial properties from the absolutely gravity-free environment (which actually does not exist). You have only to push off horizontally, for instance, along the thin line of one of the rings and, with one slight effort, you begin to move with the speed of a "mail train" in relation to the ring, either at its side or in the gaps in between; you spend your life in motion, cover millions of kilometres, and be unable to stop, unless you take the right measures; your motion in relation to the planet is, of course, 100 times faster and continues forever, in spite of you, owing to the revolution of the rings. The inhabitants of the disk hold all kinds of conclaves and meetings with the greatest of convenience and without the slightest difficulty; they have no need at all of such relatively powerful instruments of locomotion as our legs. While taking part in their meetings and outings and, at the same time, reading or doing something else, I hardly noticed the road or my own movements, feeling no headaches or aching bones because of the dust and jolting, I involuntarily had a mental vision of my own planet, the Earth. I thought of the unfortunate traveller there, blistering his feet as he walks 20 to 30 kilometres, or the rich man in his cabriolet, drenched to the skin by the rain, frozen to the marrow, and wistfully dreaming of rest and a soft bed; but what is a bed compared to the "bed" of free space you always have there—and my heart was filled with pity.

"How did the idea enter your heads of conquering space and solar energy by such simple, easy means?" I once asked the inhabitants of Pallas. And they told me the following story.

Long, long ago, in ancient times, the planet was by no means as smooth and spherical as now. On the equator

itself stood a mountain, which revolved together with the planet. We climbed vertically up this mountain, which was as much as 800 kilometres high, as easily as you, on the Earth, climb an imperceptible slope of half a degree; every jump you took would land you 30 metres higher up in half a minute; so in one second you would cover one metre (the speed of a pedestrian).

Our feeble legs could not take such leaps, but we climbed straight up, at a speed of 3-4 kilometres an hour; consequently we could cover the entire distance in 200 hours or 8 terrestrial days, or, including time for resting, in a fortnight. Later, mechanical roads with solar motors were devised and the trip up the mountain no longer presented any difficulty.

Climbing up the mountain one way or another the travellers always noticed that they felt lighter the higher up they went; they were able to jump more easily and further, the higher up they were. At a height of 700 kilometres, very heavy objects weighed less than a dram and, when given the slightest push, soared up like feathers for several kilometres, floating for a long while and falling very slowly! At a height of 750 km gravity disappeared completely. Jumping sideways, or by just not keeping close to the mountain, one became separated from it and hung suspended at a height of 750 km above the planet, with an abyss overhead and underfoot.

Imagine the situation of a rational being, who has accidentally slipped off a mountain and sees it receding to the distance! He wants to return to it, helplessly stretches out his arms and sends out plaintive appeals; but all in vain: the mountain continues to recede into the distance!

It is all well and good when there is something to catch hold of, or when you accidentally move away from it together with a lump of rock, because then, after pushing it aside in the direction opposite to your own, you can still return at once from the yawning abyss. But when there is nothing? However, do not worry, the first explorer who

ran this terrible risk did not perish. He returned quite safely to his kith and kin; he merely had a cheap round-the-world trip, true at such a great distance from Pallas, that he saw it as a brightly shining giant moon, occupying a tremendous part of the heavenly firmament (15°, or 900 times more than the Moon, observed from the Earth).

To what point, however, did he return? He came back to the same mountain two terrestrial months later, presuming he had pushed off gently enough to impart to himself the relative velocity of translation of about one metre a second.

The first traveller, who returned terrified but also greatly delighted, was followed by a legion of brave explorers, who, with all their goods and chattels, shortly formed a whole living ring around the planet. The crowded conditions on the planet, the shortage of sunlight, i.e., their source of food, spurred on the kindly folk, who desired to avoid quarrels and troubles over a crust of bread in earthly language, or sunlight—in their language.

They soon noticed that this very tall mountain impeded the formation of rings above and below. Enlightenment spread, machinery and technology progressed, and, finally, they contrived what you see here today; the mountain was removed because it produced "perturbation" in the rings, because of its gravitational attraction, and obstructed freedom of movement and expansion above and below.

And now we extend the diameter of our ring as required, concluded the story-teller.

LIVING BEINGS IN THE COSMOS*

From a purely terrestrial standpoint the animal is composed of 29 elements known to us. Its chief component is water; it can stand temperatures not higher than 100°C and not lower than 100°-200°C (but then it does not live but is preserved alive in a state of anabiosis); most of the animals require a definite average temperature, approximately 20°C. The animal requires an atmosphere containing oxygen and water vapour. The source of the animal's activity, i.e., movements and thinking, comes from other organisms, or at least the Sun (zoophytes). The animal presumably cannot live without atmospheric pressure and gravity. The animal's body temperature must be above freezing point, but must not exceed 37°-40°C. The mature animal reaches a definite size.

Even the highest animal (man) is far from perfect; for instance, the life span is short, the brain is small and of poor structure, and so on.

All this is essentially a result of adaptation to the conditions of life prevailing on the Earth, chiefly to life on the

* The article offers a broad view of the universal occurrence and variety of forms of life in the cosmos. It deals with worlds within worlds, the periodicity and complexity of matter and phenomena, which have no end; it speaks of infinitely remote epochs where there were "ethereal" animals unlike any found on Earth, and difficult to imagine, but in their way perfect and almost humanly conscious.—*Ed.*

equator, and a sign of incomplete phylogenetic development (evolution). On other planets with different conditions of life the animal will be built on different lines. Our Earth, too, will produce more perfect forms in the course of time. Let us examine, in sequence, all the available information pertaining to terrestrial organisms.

Why are the animals made up of 29 elements and why do they not contain the remaining 61, for instance, gold, platinum and others (these are sometimes found in organisms but only by chance, in negligible quantities and playing no role at all)? (And of the 29 elements probably nine are unnecessary, too.)

The first reason is that the animal feeds on plants and plants contain just these elements. And why are plants made up of these substances? Plants are surrounded by the atmosphere, water and water vapour, while their roots are in the soil, so it is natural that they should contain these substances; hydrogen and oxygen come from the water while the soil, dissolved in the water, gives the plants chiefly calcium, phosphorus, chlorine, sulphur, sodium, potassium, fluorine, magnesium, iron, silicon, manganese, aluminium and other elements. The atmosphere provides oxygen, nitrogen and carbon. Soil and water in the soil contain other elements as well, but in infinitesimal doses, because these are either rare substances or heavy, and hidden deep down in the earth and not easily accessible to the plants. If other elements predominated in the composition of soil and atmosphere, the composition of plants and animals would be different.

The upper crust of planets lying closer to the suns contains more of the heavy elements, and organisms on these planets should contain heavy elements. Organisms on planets that are far removed from the suns should, on the contrary, contain the lighter substances, because more of these occur there.

Man has extracted heavy metals from the bowels of the earth and made gold, for instance, part of his body (gold

teeth, etc.); generally speaking, the composition of animals on Earth may yet undergo a change.

What inference can be drawn from the above? Given suitable conditions, all elements can be used to build up living organisms. So we may suppose that on every planet different substances predominate in the composition of living beings, depending on the elements in the planet's crust, its distance from the Sun, the latter's properties, the temperature on the planet, and other factors.

The animal consists of solids and liquids. And water is not the only liquid. But on the planets that are situated far from the Sun—and at low temperatures in general—water is a mineral while the prevailing liquid substances are of other composition, for instance, liquid carbon dioxide, various oils, alcohols, hydrocarbons, carbohydrates, liquid gases and so on. These would form the seas and living organisms. On the other hand, bodies that are solid on the Earth would be in a liquid state on planets nearer the Sun and might become parts of the composition of the animals.

Atmospheres of other planets, too, may have a different composition with hydrogen predominating on the cold planets, and, on planets nearer the Sun—water vapour or other liquids converted into gases because of the great heat.

The conclusion to be drawn is that on cold and hot planets there may be living beings composed of the seas, atmospheres and soils peculiar to each of the planets.

Is it true that for life to develop abundantly the environment must have a temperature of roughly 25°C? We have seen that neither a high nor a low temperature deprives planets of oceans and atmospheres, only their composition is different; so animal life should also be possible on the planets. The animals will be made up of the liquids and gases appropriate to the mean temperature of the given planet. Consequently, the greatest variety of temperature on the planets are no obstacle to the abundant development of life on them.

We know that even our own organisms adapt themselves to a low temperature. True, this applies to either the lowest of the animal kingdom or to rational man, capable of creating an artificial situation to protect himself from the cold, which costs him a tremendous effort. But the northern animals have migrated from warm climes, their place of origin was the equator and they were not adapted to the harsh climate at first. Hundreds of millenia had to pass before they grew accustomed to the cold, and then not all of them. That is why so far we have not observed any luxuriant blossoming of life in winter conditions and in the polar climate. Incidentally, the main reason for the scarcity of life in cold countries is the absence of the solar energy.

Why is the body temperature of the higher animals on Earth about 37°C? Life originated at the equator, in its seas and oceans. (Why? Because of the even warmth and abundance of the solar energy.) The mean temperature of water there fluctuated around 25°C. That was the body temperature of the primordial animals, the height of whose existence coincided with just this temperature. The animals accepted the temperature of their environment, and although they could stand lower and higher temperatures they were at their best only in the mean temperature of the environment.

The body temperature of these first creatures was only slightly higher than that of their environment, since they had little vital energy.

There then developed the warm-blooded animals with their tremendous vitality. As a result of this (the warmth, the burning up or chemical processes inside the animal) their body temperature became much higher than the average temperature of the surrounding medium. Thus, the body temperatures of animals are always a little higher than the mean temperature of the planet. But planets may have widely varying temperatures, and so, therefore, can animals. Some may be very hot, others ice-cold—from man's point of view. I leave out of the discussion cases

where the temperature of the medium is a little higher than that of the animal; warm-blooded animals are then in danger of dying, because, if heated, the brain ceases to function. But actually when this happens the skin or the lungs give off water, the heat of the body is absorbed and the brain remains at its normal temperature. A certain constant temperature is another condition essential to life. Drastic fluctuations of temperature are fatal to any organism. But we know that on the few planets which have one side always turned to the Sun the temperature fluctuates between 250°C below zero and 150°C above.

How could there be life on such planets? The fact is that whatever difference there may be in the temperatures at the surface, this alone does not preclude life, because inside the planet the temperature remains constant. So animals can burrow down into the ground and hide in their holes from the excessive heat and cold. But the lowest animals would be quite helpless. The beginnings of life in such contrasting temperatures would be difficult. There are limits to everything, even to the endurance of living things; so perhaps rational beings having the highest development of knowledge and technology, might take possession of the places that are inconvenient for lower animal life.

Must there be a sun for animals to exist? The energy of solar radiation is widespread in the Universe: the Ethereal Island alone has over a million thousand millions of suns, young and old, constantly emitting their rays into space. It is clear, therefore, that most animals live by solar energy. Yet they may exist by force of some other energy. Some of the suns become extinguished and distant planets have almost no sun-rays at all, yet life does not immediately end on these planets. High temperatures and chemical energy are long preserved within the celestial bodies that have cooled on the outside. This makes it possible for different organisms to continue living for a long time. Only there is no particular need to utilise these meagre remnants

of celestial energy, since there are vast numbers of flaming hot suns! Theoretically any form of energy can support life; for instance, the energy of planetary motion and revolution, gravity, heat, atomic energy, and other kinds. But we shall not discuss in what way.

A very important factor is the kind of brain an animal has. Can it grow larger with the animal's size remaining the same, and if so, to what extent? The important thing is the structure of the brain, but size is a good quality, because the larger the brain, the more capacious the memory and the mental powers in general. We can carry heavy loads, why then can we not have heavier heads? Mechanics shows that our brain can quite safely be twice or three times as large as it is. So far, however, there are obstacles to this. First, child-birth becomes more difficult and, secondly, development of the brain (at the initial stage) leads to circumscribed moral standards and man renounces personal happiness and leaves no offspring. At the second stage this development leads to pessimism which destroys bright hopes, fills the mind with fears and is the cause of nervous disturbances and early death. Only at the third stage, with the brain and mind reaching their highest development is a degree of equilibrium established between altruism and egoism and man realises that he has a duty both to himself and his offspring.

The first obstacle can be overcome by premature births and subsequent development of the foetus in a special artificial medium. Man will, as it were, have to return to the period of egg-laying (birds, reptiles and the like). The second and third obstacles can be removed by precautions undertaken during the first and second stages of development and the immediate development of the third, which gives rise to optimism, thanks to superior knowledge, penetration into the depths of nature and great wisdom.

But the brain may grow in size in proportion to the growth of the entire animal. Growth is hampered on the Earth by gravity. Mechanics definitely proves that the

mass of the brain of animals similar in shape is proportional to the cube of the decrease of gravity to which the animals are subjected. Thus on Mars and Mercury where gravity is half what it is on the Earth the volume of the brain could be eight times larger than that of the terrestrial animals provided, naturally, for an animal with a similar external appearance. The creatures would be twice as large as on the Earth. On the Moon they would be 16 times as large and the mass of the brain 216 times greater.

This conclusion of mechanics does not apply to aquatic creatures, for their weight is counteracted by water. Animals with large brains could originate in water. But no industry is possible in a water medium (no fire can burn there), there is insufficient oxygen and solar energy (light), so life could not and did not develop there to any extent.

When man has settled down in the ether, in artificial dwellings, i.e., when he has overcome the Earth's gravitational pull and escaped from it, he will not, in interplanetary space, encounter any obstacle to the growth of his brain if we ignore the complexity of a large brain and the organs that supply it with nutriment which, of course, are bound to put a limit on the development of the mass of the brain.

But while man is on the Earth (and part of mankind will certainly remain on the Earth) his brain can increase only two or three times. It will not be beautiful, but one can get accustomed to anything. Beauty is a conventional, subjective thing.

The lungs of mammals are very imperfectly constructed. This organ ought to be transformed. Take the example of the alimentary canal. In lower forms it has an entrance for food but no special exit. What is left after food has been digested goes out the way the food came in. Locusts, for instance, excrete through the mouth. This slows down the digestive process. That is why higher animals have acquired an anus. They have an advantage over animals without it. Primitive blood circulation, again, was in waves

(to and fro). It is only the higher forms that have a decent pump (the heart) and regular blood circulation.

It is the same with the lungs of the majority of mammals who inhale air, extract oxygen from it and exhale the products of respiration through one and the same orifice. Because of this the blood is oxidised slowly, the organ of respiration has a big volume yet gives little oxygen to the animal. Like the alimentary canal, the respiratory chamber should have a separate exit; the air should enter uninterruptedly through one opening and go out through another. That this is possible can be seen from the structure of insects and birds which willy-nilly release enormous energy during flight. Insects, for instance, have respiratory tubules (tracheae) through which the air flows. All they lack is a pneumatic pump, and we can be sure that at least some insects possess one. In birds the thoracic muscles are pierced with similar tubules, although we know little of the mechanism of how the air passes through them: whether the streams of air flow in one direction or whether they fluctuate backwards and forwards as in the lungs. One thing is clear—the air current through these tubules is brought about by the contraction of the thoracic muscles during flight (just when great amounts of energy are needed).

There is no doubt that the evolution of animals even on the Earth might have taken a different course and produced animals with "through" respiratory organs. And it is quite possible that such creatures do exist on the many millions of other planets. They may originate on the Earth as well, either naturally or artificially, when man begins to model his body. Physiologists are well aware of the numerous defects in the structure of the bodies of even the highest animals. All these defects should be eliminated by means of exercise, selection, crossing, operations and so on. We have mentioned a few of the shortcomings by way of illustration. There is not a single organ in man that does not require to be improved. We might mention in passing

that in many aquatic creatures oxygen, dissolved in water, moves along with it in the same direction. In fish it travels form the mouth to the gills. Perhaps that is why fish can live on the small amount of oxygen available in water.

Is gravity, and particularly the gravity of the Earth, essential to man? In similar organisms (or ones that have an external likeness but are of different sizes) the greater the gravity the more it hampers growth. Consequently, it makes for a smaller brain and weaker mental powers. So it appears that gravity is harmful.

That the total removal of gravity in no way precludes life is seen from the fact that aquatic creatures, with gravity (or weight) counteracted by the counter-pressure of the liquid, come to no harm. On the contrary, nowhere does the size of organisms reach such dimensions as in the ocean. Quite helpless on land, the whale in water frisks like a kitten. An animal upside down does not die or suffer, although gravity operates in the reverse direction. Even less does it suffer when lying down, when the pressure of the blood column is several times less than usual. In this same position a man can swallow, digest his food and perform other actions. Apart from their therapeutic influence, baths often ease the condition of sick people by abolishing their weight. Decreased gravity should diminish the mass of the organs of locomotion (legs, feet, wings, etc.) if it does not increase the size of the organism. This is what can be expected to happen on planets with little gravity:

1. The less the radius of gravity of the planet, the larger the organism on it.
2. If this is not the case, the organs of locomotion (legs and so on) become very weak or thin.
3. If this is not the case, the animals move in longer leaps or at greater speed.
4. The three cases may be combined, that is, a moderate increase in size, moderately weakened leg or thorax

muscles, moderately increased leaps and other movements. The three extreme cases may be found in the most varied combinations.

The opposite is observed on big planets with a strong gravitation pull.

But it may be objected: How can gravity be dispensed with—the oceans will evaporate, the atmosphere will disperse and without them life is impossible.

Let us sort it all out in its proper order. Can water and air be dispensed with, and to what extent are they necessary? Man easily adapts himself to heights, where there is half as much air and oxygen as elsewhere. There are mountain villages at such heights and the children born there thrive on the shortage of oxygen while mountaineers feel the lack of it. Healthy people can, for a time, tolerate only a quarter of the usual amount of oxygen. If there are ever such things as "through" lungs people will be satisfied with still less of this vitalising gas. Fish can be said to breathe not air but water saturated with it. The water streams in one direction (from the mouth to the gill slits), just like the blood and food of the higher animals. Water contains 60 times less oxygen than the atmosphere but this does not prevent the fish from keeping alive. What is more, aquatic creatures can exist perfectly well when there is far less oxygen. It will be said: "That's just what a fish's life is like!" But pure oxygen (without water and atmospheric nitrogen), if there were such things as "through" lungs, would rapidly dissolve in the blood and give it no less than our land animals get.

But how can atmospheric pressure be dispensed with? Where there is no pressure from the air or some other medium, the result is bleeding from the nose, throat and other organs. This is understandable, for the strength of the blood vessels is partly supported by the external pressure of the atmosphere. Once there is no pressure or only a little, the weaker vessels in the nose and throat are burst by the blood. Man and the higher animals are not

adapted to weak pressure from the environment. If, indeed, in such an environment people are born and survive, it is because, in consequence of the ability of organisms (as Lamarck observed) to adapt themselves to new conditions, their blood vessels become stronger and they come to no harm in a rarefied environment.

Organs of locomotion are also articulated by atmospheric pressure. Without air this bond is disrupted. But the bones will not fall apart even without pressure from the air because they are also connected by cartilages and the constant tension of the surrounding muscles. That this is so is evident from the experience of gymnastic exercises: an athlete can hang by the arms or legs, subjected to a force of gravity many times exceeding the atmospheric pressure on the inconsiderable areas of his connecting joints. In spite of this weight the joints do not come apart. From this it is evident that muscular tension alone is enough to keep the bones articulated.

In a rarefied medium perspiration from the lungs and sweat glands should be intensified. But there are some animals (the dog) which have no sweat glands in their skin. So there can be organisms which do not lose water through perspiration. There are also some plants that do not transpire water (some cacti). What is the conclusion? That there can be creatures which would in no way suffer from the loss of external pressure. True, with lungs incapable of evaporating water the animals would be unable to regulate their body temperature and would perish. But if the temperature remains constant this danger will not be present.

There are many other indications of the influence of the pressure of the environment. For instance, the lungs of mammals expand exclusively owing to atmospheric pressure. We are nevertheless hoping that lungs will also be able to adapt themselves to the absence of gravity. And indeed, if lungs are of the "through" type, with air flowing right through them in an uninterrupted stream, they

may lose their elasticity which will become unnecessary, or they may become attached to the thoracic cavity. We cannot go into all that here.

So we see that animals can dispense with gravity and exist with a small amount of gases exerting little pressure.

Another question arises: is gaseous oxygen or any other gas-like nutrition necessary at all? No, it is not. Animals can take oxygen in, like food, in the form of its unstable compounds in solid or liquid form. Chemistry knows of numerous compounds of this kind and the chemistry of the future will discover many more. Perhaps a new organ —a kind of stomach—will be necessary, from which oxygen will gradually pass into the blood. An organism will have two stomachs and no lungs. It does not lose water and will in no way suffer without an atmosphere. Organisms of this kind are possible on the Moon and other planets where there is no atmosphere or where the atmospheres are highly rarefied.

Organisms that have lungs can exist in atmospheres of widely differing composition. Energy does not come from oxygen alone: sodium burns in carbon dioxide and chlorine. Chemistry offers many examples of the kind. And then even on the Earth there are creatures living in a carbon-dioxide medium and needing no oxygen (anaerobia). The millions of thousands of millions of planets of our Ethereal Island alone offer such an immense variety, such unforeseeable possibilities that it is unlikely that the human mind today, no matter how brilliant, can encompass them.

Is even food necessary after all? Perhaps there can be creatures who take no food, that consume no gases, water, plants, meat and salts! We know that plants can subsist on mineral substances alone, but still this is food of a kind. And the atmosphere, too, contributes to their nutrition by supplying carbon dioxide, sometimes oxygen, sometimes nitrogen (mostly through bacteria).

There are animals that are like plants, capable of subsisting on inorganic substances; there are the plant-ani-

mals (zoophytes). Their bodies contain tiny grains (chlorophyll) through whose agency (together with sunlight) they decompose the carbon dioxide of the air into carbon and oxygen. The oxygen is released into the air while the carbon combines with other inorganic substances to form sugar, starch, cellulose (carbohydrates), nitrogenous and other organic tissues that go to make up the body of the organism.

All we see from this is that plants and animals can subsist with the help of inorganic food alone in the presence of sunlight. But all the same atmosphere, water and soil also play a part here. Is life possible without the *constant* participation of these elements of the Earth, i.e., without the participation of the environment?

Let us imagine a perfectly isolated *individual* animal. Suppose that no gases, liquids or other substances find their way into its organism, and no substances can be removed from it. The animal is permeated with light rays alone. When the light rays encounter in its body the chlorophyll, the carbon dioxide and other products of the decomposition of animal tissues dissolved in the blood, they decompose them and combine with them, producing oxygen, starch, sugar and various nitrogenous and other nutritive substances.

In this way our animal gets all that is necessary for its existence. The food (what is formed in the body by the action of sunlight) and oxygen build the animal's tissues. The latter are again decomposed into carbon dioxide and other products of decomposition (urea, ammonia and others). These need not be excreted but can return to the blood and remain in the organism. The Sun's rays again act on them as they do on gaseous and liquid fertiliser in plants, i.e., transform them into oxygen and nutritive substances that compensate the loss from the constantly working parts of the body, such as the brain, muscles, and so on. This cycle goes on eternally until the animal itself is destroyed.

That such a creature is possible is evident from the following. Imagine a transparent sphere of quartz or glass, pierced by the rays of the Sun. It contains a little soil, water, some gases, plants and animals. In a word, this tiny sphere is like our enormous Earth and, like every other planet, it contains a certain amount of isolated matter and one and the same cycle of matter takes place in the Earth and in the tiny sphere. One glass sphere is just like a hypothetical being which manages on an unchanging amount of matter, and which lives for ever. If some animals within the sphere happen to die, new ones are born to take their place (the animals feed on plants). The sphere can be said to be immortal, just like the Earth.

One may ask, "How can there appear an animal whose mass remains constant?" An animal living, thinking, moving and, let us assume, not even dying. But how is it born and how does it give birth to new animals? It is conceivable that at the initial stage of its existence it develops like terrestrial animals from an ovule developing in a suitable nutritive medium (perhaps with the participation of solar energy), growing, breathing, reaching its maximum size, fertilising or producing ova, then undergoing transformations (like the caterpillar in chrysalis and the butterfly), losing sweat glands, lungs, digestive organs, becoming covered with an impenetrable skin, in a word, becoming isolated from the surrounding medium and developing into the extraordinary being we have already described. It subsists on sunlight alone, its mass remains constant, it continues to think and live like a mortal or an immortal being.

The cradle of such beings, of course, is a planet like the Earth, i.e., having an atmosphere and oceans consisting of some kind of gases or liquids. But a mature being of this kind can live in a void, in the ether, even without gravity, so long as there is solar energy. Fortunately there is no dearth of it as millions upon millions of suns, young

and old, with and without families of planets, have been tirelessly emitting this energy for many trillions of years. When some of the suns become feeble or extinguished, new ones take their place. Beings similar to those we have described cannot fail to make use of this abundant radiating energy. They surround all the suns, even those that have no planets, and utilise their energy to live and think. There must be a purpose for the stars' energy!

We have mentioned beings like terrestrial plants and animals. We are not going outside the limits of science, but our imagination has all the same produced that which does not exist on the Earth but which is possible from the viewpoint of our narrow (so-called scientific) understanding of matter.

By this we mean 80-90 elements, their transformation, protons, electrons and other working hypotheses. We have reached several conclusions that living organisms could adapt themselves to the many conditions of life to be found on millions and millions of planets and beyond them; the forms and functions of these beings are naturally much more varied than is the case with terrestrial plants and animals; the same applies to their degree of perfection, but this, in general, is far higher than the highest found on the Earth; in comparison human genius is nothing. All this is the result of a great variety of conditions and aeons of time, of which there could be no shortage whatsoever.

In the course of time unity is achieved on every planet, all imperfections are eliminated, it attains a perfect social order and the greatest power; its supreme council elects one who administers the whole planet. This one is the most perfect being on it. His qualities gradually spread to all the inhabitants but still they cannot all become quite alike.

But the planet's population multiplies and the surplus can only find room in the space around their sun. This population is many million times more numerous than that left on the planet. It, too, is administered by an elected

body and its president. The latter is still more perfect than the president of the council on an individual planet.

Then neighbouring groups of suns, galaxies, ethereal islands, and so on also unite. The representatives of these social units ascend higher and higher in the scale of perfection. Thus, besides the rank-and-file population of the Universe, which is at a fairly high level of perfection, we find representatives of planets, solar systems, constellations, galaxies, ethereal islands, and so on. It is difficult to imagine the degree of perfection they have attained. They may be likened to deities of different ranks.

One would think that perhaps there is no purpose in the solar system or in several systems being united. Let each solar system, for example, live as best it can. What does it care about some other solar system? But each sun with its planets will not exist for ever. All of them, in any case, finally explode, become extinguished or suffer various catastrophes. Before disasters happen some suitable place to live, that is not occupied, has to be found for the population. We must know all there is to know about other solar systems. The president of each group will consider what is in the common interest, he will give the necessary information and direct the movement of the societies and give them every assistance in settling in the new place.

Can communication be established between neighbouring suns? Since we can obtain some knowledge of them even now you can imagine what will happen later on, when man has begun to live in the ether where there is no atmosphere to hamper the almost unlimited increase in the power of telescopes, when we become free from the devastating force of gravity, and so on.

For interstellar distances light does not travel fast enough, it needs years and years to cover them. But perhaps a new medium will be discovered in the ether, one lighter and more elastic than the ether (just as ether is still found in the atmosphere). Perhaps its invisible vacilla-

tions will reach neighbouring suns in a matter not of years but days or even hours. Then it will be easier to discuss this problem than it is now.

* * *

All this is terrestrial, within the comprehension of the simple scientific human mind. But perhaps there is a higher point of view, less comprehensible to us. That this may be so is proved not merely by inspired reasoning but by the facts. But for this we must rise above commonplace working hypotheses—all these electrons, protons, hydrogen and the like.

Indeed, what course has the trend of scientific development, i.e., the development of knowledge, taken? At first man discovered a countless host of bodies with varied properties and took them to be an infinite number of fundamentally different substances. Later, all this variety was reduced to 90 elements. Finally the conclusion was arrived at that these 90 simple substances were made up of electrons and protons; the idea of the ether was discarded completely. But the majority of physicists still use the ether as a working hypothesis; they think of it as an extremely rarefied and elastic substance, the particles of which are many thousand million times smaller than protons and millions of times smaller than electrons.* But what tremendous leaps are those between the masses of the particles! If the mass of a proton is taken as unity, the mass of an electron will be expressed by the ratio 1:2,000 and that of ether $1:(16\times10^{12})$.

This muddle can be cleared up if we discard the narrow standpoint of modern working hypotheses.

Matter as it is at present is the result of the evolution of a simpler matter whose elements we do not know. What I mean is that at some period of time matter used to be

* See my *Kinetic Theory of Light.*

lighter and more elastic, because it consisted of smaller particles than electrons. Perhaps those were particles of ether.

When was this? Well, time is as infinite as space and matter. There is any amount of it. No number can express it. All known and imaginary times are zero compared with time. So take enough time and we shall come to simpler matter.

This "simple" matter is the result of still "simpler" matter. At some date the latter predominated in the Universe. We can go on and on without an end in this way, and come to the conclusion that matter can be divided infinitely owing to the infiniteness of past time.

Say what you will, but to consider proton or hydrogen to be the basis of the Universe, the true element, the indivisible, is as absurd as to consider a sun or a planet to be that element.

It may be that someone, some giant for whom the whole sky is only a small particle of matter, and for whom individual suns are as invisible as atoms are for us, on examining the "sky" through his "microscope", will notice the suns and will joyfully exclaim: "At last I have discovered the particles of which 'matter' consists!" But we know that he would be grossly mistaken in taking the suns for indivisible atoms.

We make the mistake taking an electron, a proton or even a particle of ether for an indivisible element. Our reason and the history of the sciences tell us that our atom is as complex as a planet or a sun.

What is the use of saying all this? What practical conclusion is to be drawn from it? I want to make it clear that the infiniteness of past time opens up before us a succession of worlds made up of substances more and more rarefied, more and more elastic. (It has been observed that with the decrease of the mass of particles their translational velocity increases as does their elasticity. Hence, in more complex matter elasticity decreases, in less com-

plex matter it increases.) I want to make it clear that our matter, too, will continue to evolve. Some time in the future worlds will arise consisting of more and more complex and massive particles. To the future generations of conscious beings, these, too, will seem at first to be atoms. But in this they will be as mistaken as we are.

"Well, what of it, what follows?" the reader may ask. And we shall answer: The epochs that have become lost in the infinity of time produced beings that achieved perfection just as beings made up of "our" matter are achieving it. Each of the rarefied worlds had its own solid, liquid and gaseous substances which served too for the formation of thinking beings (consisting of very "subtle" matter). There has been an infinite number of such epochs before us and there will be an infinite number in the future. Our epoch, with conscious beings like those on the Earth, is one of this endless chain of epochs.

Our imagination presents to us an infinite number of epochs in the past and in the future, each with its living beings. What are these beings like, is there any connection between them, how do they manifest themselves, can they manifest themselves, do they disappear with the arrival of a new epoch?

We shall give an example. Plants and animals on Earth have undergone an evolution. They sprang from a single source—very simple protoplasm. One could even say that they sprang from inorganic matter which gave rise to protoplasm, from which developed a number of very different beings. Some of them became extinct, but in general the development of higher animals did not prevent the lower, more ancient, primitive forms from continuing to exist without much progress. At the feast of life on Earth we see existing simultaneously bacteria, infusoria, worms, insects, fish, amphibia, reptiles, birds, mammals and man. True, the power of man threatens to destroy beings that are inimical to him. Others, on the other hand, are necessary for his well-being (bacteria and plants) and still

others have some kind of intelligence and are useful to him, so there is no point in destroying them.

Similarly the epochs, parts of immense and infinite time, preserved not only the denser beings of our epoch but also the lightest ones belonging to past epochs. Many of them could have become extinct, but not all of them: those more perfect and useful could have remained as beings that are useful to man.

Formerly we advocated the repetition of phenomena, or the periodic nature of the worlds, that the worlds were time and again destroyed and time and again arose. Periodicity there is, but the periods are not all alike, they seem to descend for they yield ever more complex matter. It can be compared to an undulating road: we first ascend then descend as we go along, never noticing that the road slopes downwards all the time and that at the end of each period we are on a lower level than before. There is no end, of course, to periods (waves), to the descent (the increasing complexity and density of matter).

BIOLOGY OF DWARFS AND GIANTS

THE HALF-SIZED MAN

If a man is 180 cm tall, then when he is half that size he will, of course, be 90 cm. Provided geometric proportions are observed, the bodily surface area will dwindle to a quarter, and the total volume to an eighth. The weight and mass of the body will diminish to the same extent. Our man weighed 64 kg before; now he weighs only 8 kg. The volume, weight, and mass of his brain, as well as of all his other organs will also be reduced to one-eighth. Meanwhile the surface area will be only a quarter, and the linear measurement, i.e., length, breadth and height, will be one-half. Since this should cause the capacity for logical thought to weaken, our dwarf is hardly likely to be able to comprehend and describe his sensations. We shall have to do that for him. Only with a different brain structure and a different ratio between its different segments, can he retain enough intelligence, despite the reduction in the general mass of the brain.

The total absolute emission of heat will decrease to one quarter, fully corresponding to the diminished body area. Consequently, the body temperature should seemingly remain the same as before. However, since the cold will penetrate more deeply into the body, the temperature in its central parts should drop.

The relative volume of food and oxygen consumed and of excreta should become doubled. Whereas a normal being consumes two kilograms of food in the 24-hour cycle,

our dwarf will consume half a kilogram, which in relation to the mass of his body, will be twice as much. Thus, our dwarf will be much more of a glutton. To dine, he will need a sausage twice as long and a loaf of bread twice as big—that is, of course, relatively speaking.

He will perform, again relatively speaking, twice as much mechanical work. He will be able to climb a mountain or a staircase and run twice as quckly (that is, if only friction is taken into consideration, and atmospheric resistance ignored). In relation to the dimensions of his smaller body, the effect will be four times greater. Thus in one minute, a normal person climbs a distance equal to his height; our dwarf—a distance equal to four times his height.

The absolute muscular strength will dwindle to a quarter. There will be no point in trying to fight a giant or anyone that is tall in general; the dwarf is bound to be vanquished. However, the relative muscular power will double. Whereas previously he could lift one person, now, as a dwarf, he can lift two of his own size with still greater ease.

The relative resistance to fracture of the bones and gristle will double as, too, will the resistance of the tendons and the skin. Whereas a normal person easily carries himself and another person of his own size on his shoulders, the dwarf will be able to carry six of his own size, himself included, or five, not counting himself. Apparently, the dwarf will be able to drag a log relatively twice as long and as heavy. He will be able to drag rocks twice as large in volume, and pull a cart loaded with twice the weight. The absolute height from which our dwarf will be able to fall without harming himself will be twice as great; however, compared with the size of his body it will be four times as much. A normal person can fall without harming himself from about his height; but a dwarf can fall down safely from a place four times his height.

The work performed by any muscle in one contraction dwindles to one-eighth since the tension will be a quarter,

and the size of the contraction is half as much. In consequence of this, a leap will cover the same absolute distance, but in relative terms it will be greater. Indeed, a person of normal height crouches by 30 cm when preparing to jump, and jumps, let us say, as much, raising his body in all 60 cm. The dwarf's muscles should raise him to the same height. But since he will lift himself by only 15 cm upon straightening up, he will still have another 45 cm to go, and, consequently, in relation to his height the jump he makes is 3 times as great. A normal person is able to jump on to a chair, but a dwarf will easily be able to jump on to a table. If, in performing work, the number of muscular contractions a minute remains the same, the absolute work performed would decrease to an eighth, while the relative work performed would remain constant. However, we know that the relative work performed by the dwarf is twice as great. Consequently, the number of muscular contractions per unit of time should double. In other words, the frequency of movement, the number of motions made by the limbs, the head, and so on, should double. This exactly corresponds to the faster nerve communications. The dwarf will prove to be not only a strong man, an unrivalled jumper and acrobat, but he will also be very lively, swift and agile.

The absolute height reached by stones of proportionate sizes, thrown up by hand, will remain the same, but in relation to the thrower's height it will be twice as much. Whereas a normal person can throw a stone the size of his fist to a height 10 times greater than his own height, the dwarf can throw a stone the size of his fist to a height 20 times greater than his own. Whereas the first will throw a stone over his house, the dwarf will throw the same stone over a house twice the size—of course, in proportion to his own dimensions.

A blow struck by the fist or a kick, is proportionate to the dwarf's mass; in other words, the force of the blow or kick will be 8 times weaker, since the speed at which

the hand, with or without a weapon, moves remains the same. Hence, the relative force of a blow, delivered by a fist, hammer, sword, or knife, remains constant, but the frequency with which the blows are delivered, is doubled.

The dwarf will find swimming easy, as his energy is twice as great, while the absolute velocity of the fall into the water will be reduced by practically a third. Further, the relative efficiency of the limbs is doubled as their relative surface area is also doubled.

The foregoing makes it clear that it is far easier for a dwarf to combat gravity, as he is more energetic and lively, and even swifter, in absolute terms. What, then, in the struggle for survival, prevented dwarfs from ousting people of normal height? In the first place dwarfs lose because of their diminished absolute muscular power; in the struggle against gravitation they gain, but in the struggle against creatures larger than themselves they lose. In addition, the smaller volume of the brain means weaker mental ability.

THE DOUBLE-SIZED MAN

Suppose now that instead of being 1 m 80 cm tall, our man is 3 m 60 cm tall. His volume, mass and weight will multiply 8-fold. Instead of 64 kg, our giant will weigh 512 kg. The absolute power of his muscles and limbs will be quadrupled. But in relation to his weight, it will be only half as much. Whereas a person of normal height is easily able to carry another person of the same height on his back, the giant will be unable to carry anything, all his muscular energy is used to carry the mass of his own body, which is now 8 times greater. He no longer has enough strength to work, carry loads or build dwellings. In fact, he will hardly be able to drag himself along; the slightest pressure will cause him to topple over.

True, he will possess a much greater brain power. But what use is this to him, if he is physically impotent, is

unable to work and has to spend every ounce of his strength to carry the weight of his own body. The state of being a giant may be compared to that of an ordinary healthy man of good physique, who is overloaded to exhaustion and has no hope of ever ridding himself of the load.

The effort that a giant must make to combat gravity will be four times greater in relation to his height, because the loads corresponding to his size increase 8-fold, while the height to which they must be lifted is doubled. As a result the work increases 16-fold. Meanwhile, his absolute strength will be only fourfold. Consequently, the energy available to combat gravity is reduced to a quarter. A giant of still greater height will even be unable to walk, lift or move his limbs, or perform any mechanical work. He will retain longest the ability to lift a finger, move his tongue and other minor organs. But a still taller giant will even fail to do that, as he will no longer prove able to overcome their weight. And if he is still taller his blood vessels will burst, all his internal organs will be crushed, and he will die.

A MAN ONE HUNDRED TIMES SMALLER

It is scarcely likely in this case that we shall ever be able to reproduce the internal organs of the appropriate proportions, but let us presume that it can be done. Now we are dealing with a real Lilliputian. He is only 10 mm high, his body surface area is 10,000 times smaller, while his volume, mass, and weight, are a million times less than those of a normal person. He will weigh 0.063 gr, which is just a little more than the weight of an ordinary drop of water. However, his relative muscular power will be a hundred times greater, and he will be able to lift loads a hundred times larger in relation to the mass of his body. The relative strength of his bones, gristle, skin and other supporting elements will also be a hundred times greater. He will be able to carry 200 beings like himself without

fear of breaking a single bone or pulling a single muscle. He will carry them with the same ease, with which a normal person carries another.

He will find it 10,000 times easier to combat gravity. For one and the same time the Lilliputian will dig 10,000 dugouts of a size corresponding to his height while the normal-sized man will dig only one. The canal he digs in the same period of time as the normal-sized man will be 10,000 times longer (relative to his height, of course).

Though the relative amount of work performed by muscular contraction will remain the same, the apparent size of the jump he is able to make will be a hundred times greater, in relation to his size, and, furthermore, he will be able to lift himself off the ground to a height 200 times his own. Without a running start, the Lilliputian will be able to jump over a building that appears as a 20-storey "skyscraper" to him and to leap across puddles, that seem to him as large as lakes. He will be able to throw stones just as far and just as high—which in relative terms will mean a 100-fold increase. He will swim without any effort at all as the relative power of his muscles and the surface area of his palms will be a hundred times greater.

To the Lilliputian the air—in comparison with the mass of his own body—will seem to be a hundred times denser. The force of the wind will also seem a hundred times stronger. However, he will not be helpless even in the face of a strong gale, as his muscular power and tenacity will be a hundred times greater.

Our Lilliputian can fall from any height he pleases. Atmospheric resistance will prevent him from bruising himself as his relatively large body surface area will not permit a velocity of more than 3 to 4 metres a second. Furthermore, the resistance his bones and other organs offer to destruction is a hundred times greater. Even if our midget were much larger he would be able to jump off a cloud without hurting himself.

Holding a small pair of wings in his hands, our Lilliputian will be able to fly and even carry a relatively heavy load.

* * *

Again the question arises: How was it that in the process of evolution man did not become a Lilliputian since small dimensions seem to present such great advantages?

Firstly, the absolute strength the organs of larger creatures possess is nevertheless greater and if it comes to a fight with midgets, the latter have a bad time of it. Secondly, larger creatures possess a greater intelligence and this adds to the chances of winning.

Had the gravitational pull of our planet been different, the size of that most perfect of creatures, the human being, and for that matter of all other creatures, would have changed. For instance, with a sixfold diminution in gravity (as is the case on the Moon) man might have been 6 times taller, have possessed a mass 216 times greater and a muscular power 36 times stronger. His brain would have been correspondingly larger. Thanks to his muscular power (and vast intelligence) this type of man would have been the victor, even though, in the struggle against dead nature, dwarfs would have had great physical advantages. Our 10-m giant would have been (provided all the proportions would have been observed) an awkward creature, even though able to move about and jump with the same ease as a man on the Earth, though six times more slowly, in relation to his size, of course. However, his absolute muscular power and intelligence would enable him to subdue all smaller creatures.

On the other hand, had gravity been 2.5 times greater, as is the case on Jupiter, the human race would have been 2.5 times smaller. For otherwise their own body weight would have deprived the people on Jupiter of their capacity to work and even to move about by their own muscular

effort. The human being would have been 72 cm tall, would have possessed a brain 16 times smaller in volume and weight, and would probably have had a very limited intelligence. However, since all other creatures would also have been smaller, man would have continued to be master of small living nature.

However, the highest progress in terms of machines, inventions and science, would probably have been extremely slow. We could not have expected the advances in technology that are now witnessed on the Earth and which, we hope, will in time reach unimaginable proportions. On Mars, Mercury and the other minor planets and satellites, we might have expected land animals of gigantic proportions and vast intelligence, if it had not been prevented by other unfavourable conditions, for instance, excessively high or low temperatures, an atmosphere unsuited to life, a scarcity of water and other elements beneficial for the evolution of life, etc.

ISLAND OF ETHER

By the Island of Ether we mean the whole of the *known* Universe. I shall now give you its dimensions, structure and shape.

Actually it consists entirely of shining suns surrounded by spheres with extinguished surfaces that are akin to our Earth. These spheres are called planets. The same can be said of the Cosmos. It consists of a countless host of bodies, large and small, of the most varied dimensions. Some of the larger bodies are suns in the period of their brilliance. Others, smaller in size and mass, are suns in the period of their fading, and are dark. The small bodies did not emit light for long; they soon cooled, and most [of their existence] was spent in darkness. These are the planets, their satellite moons, and a countless host of tiny bodies. Finally, we see immense gaseous and extremely rarefied nebulae. They are larger than the suns but glow faintly. These are suns in the period of genesis. Let us note, in general, that the smaller the mass of the body, the more often do we find others like it in the Universe, i.e., there are more small bodies than large ones.

Thus in this space there are mostly dust specks and less rocks and bolides; then, in order of the number that exists, there follow the minor asteroids and moons of the same dimensions; medium-size asteroids and their satellites of the same dimensions, the large asteroids and moons, the minor planets, medium-size planets, large planets, suns, and gaseous nebulae.

A sun which is linked by gravitation with other nearby suns and with small, cold, planetary spheres forms the totality called the solar system. The Universe is full of solar or planetary systems. They are very far apart, as being isolated by space. A solar system, in general, consists of several suns and a multitude of planets, i.e., of dark spheres like the Earth. Every solar system was at the outset an irregular, extremely rarefied, gaseous mass. Where did it come from? The whole of the known Universe is surrounded by a transparent and extremely rarefied material medium, called ether. Throughout the whole of it, condensation gives rise to the ordinary substance consisting of known atoms or their different parts. That is why the ethereal mass is not quite transparent. It [contains] atoms. Gravitation collects the already formed parts of matter, or atoms, into clusters, into irregular gaseous nebulae. Hence, the first stage of the solar system is the ethereal one, while the second stage is that of the irregular, scarcely discernible nebula. Condensing more and more, it becomes dense and assumes the circular shape of a nebula. This is the third stage. Condensation continues, luminescence increases, and the temperature rises. We thus arrive at a star of the fourth age, a gigantic solitary, red sun, with no companions and no planets. The initial nebula had a feeble, haphazard, irregular motion, which in the giant sun developed into motion of translation and rotation. What, in general, was the source of the initial, scarcely perceptible, motion? Firstly, there was the influence of the mutual attraction of the parts of the gaseous mass and, secondly, the gravitational pull of neighbouring masses, that is, of similar nebulae and suns. The two combined to produce an irregular motion which was resolved, as a result, into the two simple motions of rotation and translation. Of course, since this motion was never quite regular either, this subsequently caused certain anomalies (during the birth of the planets).

The giant star, as yet, revolves very slowly, and produces

a spherically shaped mass. But as the star condenses (due to the formation of more and more complex matter, possessing less elasticity the more complex it is), this rotation accelerates, the axis of rotation becomes shorter, the equatorial line extends, our ball-shaped star becomes more and more flattened, turning into a sort of pancake, and the entire process culminates in a solar explosion.

Here two things may take place: 1) The embryonic rotation was feeble, in consequence of which, before the explosion (or just prior to it), the star should have considerably condensed or become dense at the middle compared with the outer parts. In this case a ring of the type seen round Saturn separated from the giant sun. 2) In the second case, the embryonic rotation of the gaseous mass was much greater. Then before it broke up, the star possessed an almost homogeneous density as rapid rotation prevented it from becoming greatly compressed. In this case, due to the centrifugal force, it extended in one direction and broke apart like a dividing germ. This brought into being two suns of approximately identical volume and mass.

What took place in the first case, and what happened to the shining solar ring? Due to radiation, the mass of the central spheroid diminished, causing the ring to move further away and finally split off, at first into several lengthwise rings set on top of each other and then transversely, with the formation of relatively small, spherical, rarefied, relatively small shining suns.

This is when child-planets are born. These child-planets—of which there may be several dozens or hundreds—move farther and farther away from their parent, due to the central luminary's loss of mass and to tidal causes, and create a [shining] planetary system. Actually, we now have a heap of large and small suns. Subsequently, the smaller ones cool, become covered over with a solid crust, and completely cease to shine. If they can still be seen, it is only because they are illuminated by the sun. After the

small planets, the other bodies successively cool down, in the order of their size. There thus comes into being an ordinary planetary system akin to our own.

However, before they cooled entirely, the planets gave birth to satellites or moons, in the very same way as their parent, the principal sun, gave birth to them. Now it is clear for us why all the planets, their satellites, and the sun itself move and rotate in one direction. All these motions were imparted to them by the Sun. We can also understand now why the planets are so far away from the Sun. They drew farther and farther away from it, as they are now doing, owing to the Sun's loss of mass and inductive deceleration.

As the planets separated and moved farther away from the luminary, its rotational force grew weaker and weaker. It was spent in making the planets move and draw farther away. After more or less prolific child-bearing, there always comes a time when one can no longer expect further "fertility" from the weakened and [aged] sun. The ring most likely separates once. Only then does it split lengthwise and transversely, creating the planets.

In the second case, the parts of the broken-up Sun, which came to have almost equal proportions owing to their loss of mass due to radiation and to tidal deceleration, also moved farther apart and formed a double star, a double sun.

In the process of further condensation, each of these two suns could have undergone either the first or second process described above (according to the conditions), giving rise to planetary systems or double suns.

There thus came into being in the heavens triple and multiple suns drawn together by attraction. We mostly see double suns (30 per cent), fewer triple suns, and still fewer quadruple suns, etc. In practice we may find a complex sun consisting of as many as seven shining members. We have examined the two extremes, or rather the two typical phenomena. However, between them lie a

multitude of secondary, intermediary phenomena. Actually, we have an almost continuous chain of such phenomena. Let us take only a few of its links. Let us imagine several gaseous nebulae of identical mass and volume, but possessing different embryonic speeds of rotation, from nil up to the greatest possible velocity. We thus get the following stars that actually exist.

1. *A solitary sun with no rotation and no planets.* It has no children and therefore no grandchildren. As it has no rotation, there is nothing to produce centrifugal force (which causes the mass to break up). Such a sterile sun is a very rare and unlikely case, but we cannot deny that it may exist in the infinite extension of the Cosmos.

2. *Feeble rotation and hence extremely powerful central compression.* The ring failed to separate because the cold, small sun was unable to achieve a speed of rotation that would overcome the force of attraction.

3. *One not massive ring separates,* and subsequently moves away to become a planet.

4. A more massive ring separates, and subsequently produces several rings and planets.

5. More rings and still more massive planets.

6. A multitude of rings and planets with a considerable mass.

7. A double sun that after separation has a smaller mass. Further compression of each sun may give rise to everything described above.

8. A double sun with equal masses.

9. A triple sun.

10. A multiple sun. Each of the suns in the last four categories may give rise to what has been described above in the case of a solitary sun.

Generally speaking, the aggregate mass of the planets is the greater, the higher the category, or the greater the embryonic speed of rotation of the gaseous nebula. However, what happened further to the solar systems, that is to systems with suns and planets?

Both had matter that was much more complex than elementary, ethereal, or less simple matter (electrons, for example). Hence, the process of disintegration predominated in them. At first it gave rise in the bodies to an even radiation, then an uneven radiation, and, finally, explosions. The intervals between explosions lengthened while the explosions themselves came to be more and more terrific in force. We shall now try to explain what caused these explosions. While the matter was gaseous and mobile, there were no explosions. However, the central pressure, the condensation of matter, its cooling, began to obstruct the unintermittent emission of electrons, ether, or other elementary, and consequently unusually elastic, matter. Then it became periodic. That is, the elastic matter accumulated in the celestial bodies until it was strong enough to overcome such obstacles as friction, thickness, hardness, etc. Then an explosion took place. The more powerful the resistance offered by the cooling and condensation of the matter, the more time was required to overpower it. Therefore, both the force of the explosions and their periodicity, in the case of each star, increased as the star aged.

There is a particular class of stars (the cepheids). The larger, the brighter they are (true, and not apparent, brightness), and the greater their central pressure and condensation. The greater, therefore, the resistance to explosion, and the greater its periodicity and force. It has even been established that the interval between explosions is proportional to the absolute brightness. This has enabled us to determine the absolute brightness and, consequently, the distance of the stars from us. So each ageing star begins to explode with ever greater force but less often. Thus at first it loses its matter through even radiation and later through increasingly powerful explosions. At times the cepheids explode with such force that in one second they radiate more energy than our Sun radiates during many years. Thus, on the one hand, we have nebulae and

suns arising everywhere from the ethereal medium, and, on the other hand, these same nebulae and suns disintegrating and being dissipated into the ether, serving partly to supplement the self-generation of nebulae from the ether. Neither do the small bodies, the planets, escape the fate of an explosion. This disaster should overtake them even before it does the suns. Indeed, since their central pressure is not great, there is less resistance to prevent the elasticity of the disintegrating matter from triumphing over attraction. It may well be that our planets too, for instance the Earth, exploded more than once. However, the mutual attraction of their parts caused them to gather again into a single mass. A tiny planet (much smaller than our Moon) that existed between Mars and Jupiter, most likely exploded at some time or other, and its parts failed to unite again, thus bringing into being a swarm of angular-shaped asteroids. The fragments were unable to merge again into one planet for the following reason. The planet exploded not at once into a multitude of fragments but, for example, into two halves, these two halves later exploding again, and so on. The phenomenon could have been so complicated, that considering, furthermore, the attraction of Jupiter and the other planets, the asteroids became independent baby planets. By virtue of all that has been said, we see that death reigns in the Universe just as much as birth. The general [picture] remains unchanged.

The Island of Ether is permanently made up of:

1) Embryos of matter in every region of the ether. They either arise of their own accord from the medium or are ejected by celestial bodies.

2) Irregular gaseous nebulae as a result of attraction.

3) Planetary (i.e., with a spherical form, like a planet) nebulae, the progenitors of suns.

4) Giant, solitary, red suns.

5) Yellow suns of a smaller mass and size but of a greater density and temperature.

6) White suns of still smaller dimensions and mass but of a still greater density and temperature.

7) Blue suns of still smaller dimensions and mass but with a higher density and temperature.

8) White suns in which the temperature, mass and dimensions are still smaller, but the density increases.

9) Yellow suns. Their temperature, volume and mass are still smaller, but their density continues to increase. Explosions are frequent and feeble.

10) Red dwarf suns. Their volume, mass and temperature are still smaller and only their density increases. Explosions are less frequent, but are of a greater force.

11) Faint stars. Explosions are still stronger.

12) Invisible suns that have cooled on the surface like planets and that explode periodically until they completely disperse into the ether. Incidentally, all suns, except the young giants, explode.

We do not know at which time during this age of the star, at which of its periods, suns and planets begin to give birth. This incidentally depends on the embryonic speed of the progenitor-nebula. Noting merely the suite of suns and their progeny, we encounter the following planetary systems (that either shine or are dark):

1) Suns devoid of planets. They can be of all ages provided there is no rotation.

2) Suns with only one planet.

3) Suns with two planets.

4) Suns with several planets.

5) Suns with very many planets.

6) A sun with a smaller sun (a double sun), each having many planets.

7) A sun with a companion of the same size (with another sun). Both have planets.

8) A triple sun with planets.

9) A multiple sun with planets (with the exception of tiny Vulcan).

Most frequent are the average conditions, the average

embryonic speed of rotation and the average number of planets. We cannot say for certain that our planetary system is an average case, because about 30 per cent of all the suns are double suns. Rather it is a system with few planets of small size. Indeed, our most massive planet Jupiter is a thousand times smaller in mass than its parent Sun. What is more, the mass of all the planets of our system is some 700 times less than that of the central luminary. Probably most solar systems, after their period of generation, are richer in planets than ours. They have bigger families, especially the double suns. It is only our own planetary system (with all its small fry) that we know pretty well.

The diameter of the orbit of our planet Neptune is less than 1,000 million kilometres. That is precisely the size of our planetary system (not counting tiny Vulcan). The distance of the nearest solar systems is nearly 40,000 million kilometres, or, in other words, a little more than 40,000 times greater than the size of our system. Generally speaking, the distance to the neighbouring solar systems averages around 400,000 million kilometres, which is 400,000 times more than the size of our system. This shows that the dimensions of the solar systems are very small compared with the space which separates them. Between them they have terrifyingly vast deserts of ether.

Roughly from 10 to 500 thousand million solar systems have been discovered with the aid of the telescope or photography. They comprise the Milky Way. A [somewhat] strange name. It is in the shape of a flat pancake or a curl. In its centre the stars are near neighbours, but the closer to the edges, the farther apart they become. To determine the dimensions of the Milky Way and [other systems], let us use another unit of time called the light year. Though really a little under 10,000 million km we shall take it to be exactly 10,000 million km. This is the distance that light travels in the course of a year ([covering] 300,000 km/sec). In terms of these units our planetary

system will equal to 10 hours in size, or, in other words, it will take light 10 hours to travel the entire diameter of Neptune's annual journey. At a distance of 3,000 of these units from the centre of the Milky Way, the number of suns already drops to one-tenth, or, in other words, they are a little more than twice as distant from one another. At a distance of 15,000 light years, there are hardly any stars at all. This is where they are farthest apart. The Milky Way is therefore taken to be 30,000 light years across. This is the diameter of the flat pancake of the Milky Way. Its thickness is one-sixth of this, i.e., 5,000 light years. But that is not all there is to the Milky Way. . . . Beyond the stars of the Milky Way, the void of ether contains more groups of suns which are called stellar clusters or stellar accumulations. They are, as it were, the continuation of the Milky Way pancake and consequently belong to it. Though they extend its diameter, they do not make it thicker. In these groups the stars are closer together than in the centre of the Milky Way. In some instances, they are 3,000 times closer together, which means that there the sun is 14 times nearer than in the centre of our Milky Way.

The cluster has more stars in the middle than at its edges, just as in the case of the Milky Way. The clusters are roughly of the same size. They have diameters of around 500 light years. But they are situated much farther away from the edges of the Milky Way. The latter with its sun clusters has a diameter of already as much as 300,000 light years. The stars and stellar clusters move in various directions. Their paths seem to be straight. The cause of the motion is, of course, the attraction exerted by the totality of stars in the Milky Way. Some people have noticed certain regularities in the movement of the suns: namely, two or three streams of stars. The velocity of the stars and their clusters is usually between 10 and 100 km/sec. The stellar clusters on the edges of the Milky Way have long been attracted towards it and possess a

velocity of as much as 100 and more kilometres a second. Incidentally, stars, too, move at times with unusual rapidity, travelling as fast as 500 kilometres a second.

I said that most of the stellar clusters are located in one direction or in one plane with the curl of the Milky Way, thus comprising one group with it. However, other nebulous splotches distributed evenly throughout the heavens are to be observed. W. Herschel thought these were other milky ways, but was later assailed by doubts. For a long time afterwards they were believed to be sections of our own Milky Way, gaseous nebulae, the embryos of suns. But when telescopes and photography improved, they were seen to have separate stars and to display solar explosions. Their extreme faintness enabled us to conjecture that they were tremendously far away. It was found that these spiral splotches lie far beyond the boundaries of our Milky Way and the stellar clusters, at a distance of millions of light years. No wonder that for so long they could not be distinguished from gaseous nebulae. Now the conviction is increasingly growing that these splotches, which often are shaped like curls and are therefore called spiral nebulae, are nothing but remote galaxies similar to our own Milky Way. Consequently they also contain thousands of millions of planetary systems. It is claimed that there are millions of other galaxies. They are millions of light years apart, while the diameter of the entire group of these other galaxies is hundreds of millions of light years. In my *Kinetic Theory of Light* I demonstrated that ether spreads to a distance of only several hundreds of millions of light years. Then it becomes rarefied beyond measure, just as the top strata of our atmosphere do. Beyond the boundaries of the ether lies another kind of matter which is incomparably more rarefied. That is why I have called the known group of galaxies the Island of Ether. Beyond it there probably lie other similar islands, but we cannot obtain any information about them, as light is unable to propagate through the etherless voids between them.

Our Island of Ether races along with all its ether, into the unknown at an unknown speed of tremendous proportions. We are unable to ascertain this speed, as we cannot see the other islands of ether.

The velocity of the spiral nebulae, i.e., the other galaxies, is of the order of thousands of kilometres a second. But this is a relative velocity, i.e., in relation to the ether or Island of Ether, which is considered stationary.

So to sum up: a planetary system is a group of celestial bodies consisting of one or several suns and a multitude of Earth-like planets. They are located in one plane and move and rotate in one direction. The entire system races along in a straight line, at a speed of between 10 to 100 or more kilometres a second. Its dimensions are of the order of thousands of millions of kilometres or dozens of light hours.

The Milky Way consists of thousands of millions of gaseous nebulae and suns that are either childless, have families (i.e., planetary systems), or are fading. The explosions of the fading suns fill space with a host of comets and help to create new gaseous nebulae.

The comets are, in all likelihood, really sun-spewed clots. Most of them fall back on to the sun, but a few, the luckiest ones, have a velocity greater than the attraction of the suns and are either comets, which have been in circulation for a long time, or vagabond, periodless comets dashing to and fro between the suns from one luminary to another.

Suns of all ages are separated in the Milky Way by vast expanses of space, measured in hundreds of thousands of millions of millions of kilometres, or dozens of light years across. These voids are hundreds of thousands of times larger than the planetary systems. They move in a straight line in all directions and only after millions of years do their paths curve. As they thread their path through the Milky Way, they waver inside it and may escape its sphere of attraction.

On the outskirts of the Milky Way we have as its continuation the stellar clusters. They are what might be called miniature galaxies. They are hundreds of light years across and thousands of light years apart. There are not very many of them. They move rapidly and seem to fall towards their Milky Way.

The Island of Ether is made up of a limited spherical mass of ether and galaxies, including our own, that float in this ether. There are millions of them, that is, spiral nebulae. In size they are like our Milky Way. The distance to the nearest is millions of light years. Consequently the voids between them are dozens of times larger than they are. The entire Island of Ether contains many thousands of millions of millions of suns of all ages and millions of millions of millions of planets.

However, even the Island of Ether is but a small (even infinitely small) part of the unknown Universe. As a drop is small compared with an ocean, as an atom is negligible compared with the Earth or the Sun, so is the Island of Ether imperceptible compared with the unknown Cosmos. But even that is not correct, because it is still infinitely more majestic.

<...>

Of the limited character of our knowledge, the same can be said as is said of the Earth, the Sun, the Milky Way and the Island of Ether: it is immeasurably small.

BEYOND THE EARTH'S ATMOSPHERE

Experiments have begun with reaction-propelled automobiles and planes. Calculations show that these experiments will not result in an improved automobile or aeroplane, because the use of explosives in motoring or aeronautics is uneconomical, considering the speeds explosives can attain in the air. However, these experiments have another extremely important aspect. The reaction-propelled automobile and aeroplane, built according to the design indicated in my composition "*The Cosmic Rocket*". *Practical Preparation*, will teach us how to pilot rocket planes and soar higher and higher.

At great altitudes we shall need a pressurised cabin with oxygen sources and absorbers of human excreta. Ascents will gradually go beyond the boundaries of the troposphere and, in the process of testing and improving the aeroplane, will reach airless space. The return to the Earth will be effected by gliding. This will be something like rocket shots, like leaps into the air, which may lead to flights beyond the atmosphere.

The absence of atmospheric resistance there and centrifugal force when the velocity is around 7-8 km/sec, will impart to the rocket plane a stable altitude outside the atmosphere and outside the Earth. The apparatus will become an Earth satellite, a tiny moon, and its stability will be the same as that of any planet satellite. Everlasting motion and eternal constancy.

Were it not for the spoiling of the air inside the rocket, and lack of food, there would be nothing to prevent us from ending our lives peacefully and happily in ethereal isolation.

The rocket must have portholes to let in the sunlight and prolific plants capable of purifying the air inside the rocket and of supplying fruits suitable for food and for maintaining strength.

Light pressure will enable the projectile to move away from the Earth and enter its orbit, to approach or move away from the Sun and, in general, to travel within the limits of our solar system.

Though this is something still remote, we would like to describe here the phenomena and the conditions for plant and animal life in the ether presuming that arrangements have been made for a man to exist in special living accommodations, in the capacity of a tiny satellite of the Earth or the Sun.

Suppose our rocket is somewhere on the Earth's orbit, but is far away from the Earth itself. Incidentally, it makes no difference where it actually is, as long as it moves as freely as any celestial body. Then nearly all the phenomena will take place just as they do in the vicinity of the Earth (outside the atmosphere). Only when the rocket is very close, the Earth will tend to act on it by the warmth it radiates, and in addition, by periodically casting a shadow on the projectile, will produce alternately day and night.

Let us assume the simplest conditions, when the distance between the rocket and the Sun is equal to the distance between the Sun and Earth and the distance separating the Earth from the rocket. Both conditions are observed when the rocket is on the Earth's orbit, but at a point diametrically opposite to the planet.

We have everlasting day and virginal sunshine. Naturally, we have no clouds, foggy weather, winds, dampness, storms, earthquakes and the like. But closing the shutters can always, when we wish, give us the darkest of nights.

Before they fall on the human being, the Sun's rays must pass through ordinary window glass, otherwise the living creature would be killed by ultra-violet rays. Plants could be given light through quartz glass as well. It is possible that for some of them this would be beneficial.

The temperature inside the rocket will depend on its design and surface properties, just as the temperature of any planet. But we cannot yet regulate the temperature of the planet, because the planet itself is so enormous, and the people are weak and few in number. However, we can easily regulate the temperature inside the projectile; we can obtain temperatures ranging from —270°C to +150°C. This cannot be done with the structures on the surface of the Earth, because they are surrounded by air which sometimes warms and sometimes cools them. But the rocket is surrounded by a void. To get the highest temperature inside the projectile, the part of our abode which faces the Sun must be made transparent and penetrable to the greatest amount of sunshine. In addition, inside the rocket the sunshine must fall on a dark surface which absorbs rays of light. The shady part of the dwelling must be given one or several shining silvery surfaces which retain the rays of heat and light inside the rocket and prevent them from escaping into celestial space and thus cooling the dwelling.

To obtain the lowest temperature, the rocket must be turned round so that its shiny surface faces the Sun, while its transparent side remains in the shade. Then the Sun's rays will be reflected without warming up the rocket, and its warmth will freely escape into space through the shady side.

The surface of the rocket could be made a sliding one and then without the rocket itself having to turn round, the desired temperature could be obtained—from —270°C to +150°C.

Can anything of the kind be achieved on the Earth? How convenient it would be for life in general, for technology, for animals and plants. We could apply various

degrees of heating for the purpose of disinfection, technology, medical treatment and public baths, to warm the aged, the infirm and new-born babies, to liquefy, to freeze, and to store small volumes of gas, to cause plants to germinate better, and so on. Then not only would firewood and artificial lighting become unnecessary, but by employing special devices, it would be quite possible to have furnaces giving the temperature of the Sun (which at its surface is between 5000° and 7000°C). But we shall not deal with this here. At any rate, such a temperature would relieve us of all need to use fuel in technical production processes.

The dwellings and the objects inside and around them are attracted for many hundreds of kilometres by one and the same force of gravity, which is the resultant force of many component forces, including, among others, the gravitational pulls of the Sun, the Earth, the planets and the stars, etc. This resultant alters the velocity of the rocket and all objects around it in absolutely the same way as does the current of a river, carrying a bundle of wood chips. Therefore, if the objects in the rocket were in a state of relative rest, this state would not be disturbed, no matter how long or how intensively the forces of gravity were to act on the rocket and objects in it.

In short, the rocket with its sections and the objects both inside and outside it, is, as it were, rid of gravitational attraction. The inhabitant of the rocket, whether inside or outside, will weigh nothing. On a planet, for instance, all bodies fall down. On the rocket this does not happen. On the Earth we have above and below. On the rocket this is not so. On the Earth tall, slender objects should [rise] upwards and objects [thrown up] fall down again. But an object thrown from a rocket will not return to it at all. It will fly away altogether (strictly speaking, it will remain on the rocket's circular orbit around the Sun; only in the sphere of cosmic velocities will it move away from the Sun and may even abandon it altogether).

All the Earth's bodies (even its gases) are bound to it by the force of gravity; they are fettered to it with chains of gravitation. However, there is no force binding anything to a rocket: anything ejected from it will move away from it for ever. Gas disperses. The attraction the rocket itself exerts is difficult to detect, it is so small. On the Earth walls topple down, old buildings are demolished by gravity and even mountains crumble away, a man may stumble into a pit and hurt himself. In ethereal space there is none of this. All the buildings, no matter how weak the material from which they are made, or how absurd and huge they are (with dimensions running into hundreds of kilometres), will remain intact.

How advantageous for ethereal structures! An absolutely unpropped or unsuspended object that is stationary (in relation to the rocket, of course) will remain stationary for ever. A rotating one will spin for ever. The position of a person devoid of all support is a tragic one, because without motion of translation, he will not be able to move an inch, despite his every effort. Strictly speaking, all that remains stationary is the object's centre of gravity. The human being may go into any contortions he pleases, strike any pose, move his limbs, and, of course, talk, provided there are gases around him.

But if there is some support: a wall, a rock, a clock or a hat, it is enough just to push oneself away from it, or throw something, for one to move steadily and in a straight line until halted by some obstacle, a wall, an object, a blow, by some force, by the resistance of the air or by some other medium.

In the ether this constancy of motion is also a tremendous advantage. There it will cost nothing to switch things from place to place, even over thousands of kilometres, because a velocity once acquired will never vanish without cause or unless obstructed. Then horses, motor-cars, railways, steamships, airships, airplanes, and even (dear me!), legs will be quite unnecessary. Legs will be useful

only as a source of muscular power. Engines and motors will be needed only to perform work, but not to move about. Thus they will be required to saw, forge, press, roll, crush, and so on.

In a seeming absence of gravity, a human being may take any direction. Above will be where his head is and below where his feet are. But with time this illusion will disappear.

Objects do not press on one another. Therefore, there will be no need for furniture, for tables, beds and pillows (in place of furniture we shall have light nettings and gratings on which to place things or hold them in position). Together with the ability to produce the desired temperature, this will rid the human being also of the need to wear clothes and footwear. What an incomparable relief!

Absence of gravity cannot harm the human being while for plants it is even beneficial. Even on the Earth people almost lose their weight when they get into water, and this is only harmful to the full-blooded, the infirm and the aged, as it increases the flow of blood to the brain. The recumbent position also reduces the blood pressure (due to weight) almost to nil. To lie recumbent for a period of years could not cause death. But when lying recumbent on the Earth some amount of pressure is exerted and this causes bed-sores. In the ether this does not happen. Finally, people can even tolerate being upside down, when the blood pressure is directed in the opposite direction. It is clear that the absence of gravity can do no more harm than bathing or lying down. And young organisms born in the ether will quickly adapt themselves to the weightless environment. Lying down is irksome because it goes hand in hand with idleness, which is not the case in the ether.

The absence of this force does not disturb any human functions. One can swallow, drink, eat, and excrete on the Earth not only when in bed or in water, but even when upside down. This clearly shows us that the same func-

tions can be performed in the ether. Even if a force o: gravity were needed to facilitate these functions, it would be easy enough to obtain such a force in the ether by causing the rocket to rotate. The centrifugal force thus produced differs in no way from gravitation. This is convenient, moreover, because this artificial gravity can be regulated at will. Its magnitude will increase with the speed of rotation. The latter costs us nothing, as rotation in a void never stops, or, in other words, does not call for an endless expenditure of energy.

What is the advantage of terrestrial gravity to plants? It merely destroys heavy, old tree trunks, bends branches and breaks them (especially when the fruit is abundant) and prevents the saps from rising to any considerable heights. Plants spend a great deal of substance and solar energy to no avail in order to grow their trunks and branches, which, were it not for gravity, could be much thinner and lighter.

The sole inconvenience of life in the ether is that of maintaining all round the human being a certain amount of gas pressure, which is something that terrestrial beings, especially the primates, cannot dispense with. Gases consist of mobile particles and to keep them in place requires a solid, firm envelope with no openings. Any rent would let the inside gases escape and without them an animal would perish. However, in the ether dwellings can be arranged so as to have many chambers, each chamber being isolated. As soon as the envelope of one of them is damaged and the gas begins to escape (which a manometer would indicate) people will immediately take steps to remedy the situation or move temporarily to the neighbouring undamaged compartment, closing the passage tight behind them.

To perform work in empty space and, in general, to emerge into the ether, special gas impervious clothing, like diving-suits, having a supply of oxygen and absorbers of human excreta would be needed.

Incidentally, after spending hundreds of years in the ether, man would gradually become a little altered himself and the void, absence of gas, and direct sunlight would not immediately kill him as they do now. The void hazard should diminish. Meanwhile, that is for the initial period, the human being will have to regard the expanses of ether around him either through the windows of his dwelling or through the visor of his space-suit.

On the sunny side he will see the Sun that is bluer than it seems to be through the Earth's atmosphere. On the shady side, with his back turned to the luminary, he will see a black sky studded with non-twinkling, multicoloured stars. They will be arranged in the same pattern as that observed from the Earth, only the latter will appear as a small star while the Moon will be a similar tiny spark, but emitting a much fainter glow.

The position of a person in protective clothing, all alone out in the ether, and the sensations he will experience, are of interest. He will have nothing overhead or underfoot, that is no support, no ground, nothing to suspend him. He will feel he is the centre of a tiny black sphere spangled with a countless host of stars. It will seem that he has only to stretch out his hand to touch them. The illusion is striking. The Universe will seem totally insignificant. The deception of nearness stems from the extreme brilliance and distinctness of the picture of the stars and their infinite distances. On the Earth, the atmosphere casts a shadow on objects and that is why they seem darker and more vague the farther off they are. But as there is no atmosphere in space, nothing casts shadows and therefore the stars seem to be near, and all at equal distance.

A few more words about the plan of work that should be followed to make a spaceship.

We do not know the details of the experiments with reaction-propelled automobiles. At any rate they will teach us much. I have already indicated the direction we must follow. If this direction has not been taken so far, it is

merely a concession to the practical side of the work, because the road indicated is no easy one. But with time it will nevertheless be taken. Now I shall briefly recapitulate.

The explosive elements must be contained separately and pumped into the explosion tube. This guarantees safety and rids us of heavy tanks. The tube must be tapered at an angle of 30°. This makes it hundreds of times shorter. It must be cooled. A reaction-propelled automobile must have three types of control surfaces for flying both in the air and in the void, while the explosion is taking place. These should be elevators, fins and ailerons, placed in the gas jet in the exhaust nozzle. Then they can be made thinner, lighter and more durable and operate more smoothly.

At first we must practise operating the rudders of direction and altitude. For this purpose the automobile has one cross axle with two wheels at its end. We can first practise operating the rudder of direction, and then both rudders at once.

Then we shall need an automobile with one wheel and we must in addition practise operating the fin-stabilisation rudders. These experiments should be conducted on the ground, not in the air.

When we learn to control all three rudders, we can add a pair of wings to our automobile like those of the aeroplane. However, flights should not and cannot continue longer than the time taken to use up the explosive material, because without the explosion our automobile rudders will either not operate at all, or will be inefficient (as these rudders have a very small surface area).

To take off and control the aircraft after the explosion another system of rudders is required, with a greater surface area, like that of an aeroplane. With these two systems we can gain height and speed until the explosives are consumed, and then glide down, which cannot be done without the aircraft-type system of rudders.

These two rudder systems (though they may be combined into one) are necessary for flying beyond the atmosphere,

as wherever we fly to, even into space, we shall have to return to the Earth by gliding, once all the explosives are used up. For it is not possible to rely on a permanent store of them.

Only by innumerable dangerous experiments is it possible to work out a design of the interplanetary spaceship. All the existing projects are merely schematic or fantastic. The critics of reaction-propelled automobiles and aeroplanes quite rightly regard the reaction method of propulsion as unacceptable because it is uneconomical. Vallier merely shows us methods of reducing the high cost of this type of locomotion. The method of reaction propulsion can be really economical when the thrust velocity approaches the velocity of the projectiles. That happens only in the case of spacecraft. Meanwhile, for Earth and aerial projectiles, the methods must be used that I have described in my "Atmospheric Resistance and the Express Train".

SCIENCE FICTION IN TSIOLKOVSKY'S WRITINGS

By B. N. VOROBYOV

"Even the discovery of the differential and integral calculus would have been inconceivable without imagination. Imagination is a quality of the greatest value."

V. I. Lenin

The name of Konstantin Tsiolkovsky, father of the theory of jet propulsion and interplanetary travel, is world famous. This great Soviet scientist who made such a signal contribution to cosmonautics, aerodynamics and aeronautics, also wrote many remarkable works of science fiction.

In the process of Tsiolkovsky's investigations his science fiction was often, as it were, the initial "trying-out" of new ideas. The scientist himself made a remarkable statement about this sequence of the creative process in his book *The Exploration of Space by Reaction-Propelled Devices*, first published in Kaluga in 1926: "First, inevitably, the idea, the fantasy, the fairy-tale. Then scientific calculation. Ultimately, fulfilment crowns the idea."

This was the path he followed in working out the problems of jet propulsion and interplanetary travel. A real pioneer in these absolutely new domains of human endeavour, Tsiolkovsky also sought by his works of science fiction to condition the public mind to accepting such ambi-

tious projects as the practical preparation for man's breakthrough into cosmic space. In addition, to write his science fiction, he had to make the necessary calculations, at least in rough, so as to put his preliminary conclusions to the test. He then developed his ideas in order finally to crown his effort with a completed scientific treatise based on a full and scrupulous mathematical analysis.

Thus Tsiolkovsky's science fiction on a subject that had caught his fancy induced him to tackle and scientifically develop new problems. He describes this in "Is This Mere Fantasy?", an article he wrote in 1934-35 when chief scientific adviser for the SF film *Cosmic Journey*.

"There is nothing that engrosses me more," he wrote in the Soviet youth paper *Komsomolskaya Pravda*, on July 23, 1935, "than the problem of overcoming terrestrial gravity and of making flights into space.... I am already 78 but I still continue to compute and design what concerns reaction-propelled machines. The things I have thought about, the ideas that have surged through my brain! This was no longer fantasy, but exact knowledge based on the laws of nature; new discoveries and new compositions were in the making. But I was also attracted to science fiction. Many times I essayed the task of writing about space travel but wound up by becoming involved in exact compilations and switching to serious work. Science fiction stories on interplanetary travel carry new ideas to the masses. All who are occupied with this are doing good work; they excite interest, promote the working of the brain and bring into being people who sympathise with, and will in the future engage in, work on grand projects."

This point is confirmed by Tsiolkovsky's science fiction works which provide in embryo the ideas underlying the discoveries and inventions that were later to immortalise his name. Of great interest, consequently, are both his finished works of this genre, and his rough fragments and outlines, since they mostly date back to when he was working out the fundamentals of the new science of *astro-*

nautics, the realisation of which by our generation has initiated the new space age in man's history. As the world has now seen, the translation into life of the propositions that Tsiolkovsky put on such a firm basis, has transformed astronomy, one of the oldest of sciences, from a purely speculative branch of knowledge into one dealing with direct experiment.

Tsiolkovsky's science fiction was bound to be a concomitant and at times forerunner of his major theoretical treatises and inventions. It is extremely characteristic of his creative work, being, in fact, the type of "conjecturing", which Lenin so greatly appreciated and which G. M. Krzhizhanovsky referred to, when he said that he "adored people who could conjecture". Tsiolkovsky was most generous with his conjectures, at once imparting them to others, and making them part and parcel of his work.

Graphic illustrations are the still extant pages from Tsiolkovsky's very first notebook of a young man which dates back to 1878-79. While in Ryazan, awaiting his appointment as schoolmaster, he poured dreamily over this notebook, pencil in hand, making fantastic sketches of vehicles, and devices, writing the first rough copy of a future monograph dealing with "free space". Tsiolkovsky had just turned 22. Later, his fantastic conjectures, accompanied by strictly substantiated mathematical analysis based on the laws of physics and celestial mechanics, took tangible shape in the world's first design for a spaceship with a jet thrust, becoming the scientist's point of departure for further work in this field.

The ten science-fiction stories in this collection relate to different periods of Tsiolkovsky's work between 1893 and 1929. This is only a small part of his many publications and manuscripts. However, they were significant as being the initial stage of the elaboration and preparation for publication of the scientist's basic works on jet propulsion and interplanetary travel. *Free Space*, the first monograph on this subject, written in Borovsk in 1883—a work very

close in character to science fiction—was the first to suggest jet engines for spaceships.*

Tsiolkovsky was able to find strikingly brilliant colours and words for his science fiction. Nevertheless—and this is what is particularly valuable about them—he never departed from science proper. His science fiction is imbued throughout with the profound conviction that this was precisely how man would finally undertake these daring projects, even though, as he assumed, at some remote date. This unshakable, and attractively expressed conviction infects the reader and compels him to stop and reflect on Tsiolkovsky's picture of space conquest.

How was it that Tsiolkovsky came to write science fiction?

In 1892 an important event took place in Tsiolkovsky's life; he was transferred from the modest post of arithmetics and geometry master, which he had held at the elementary school of Borovsk, to a similar post in the larger, provincial town of Kaluga. He found himself better placed than he had been in Borovsk. In Kaluga he met people associated with literary work, who interested themselves in his scientific researches, which he continued parallel with his teaching, and also tried to give him every assistance. Their help took the form, primarily, of getting printed in Kaluga the second part of his *Guided Metal Air Balloon*, the first part of which had been published in Moscow in 1892, and a year later of publishing in the Moscow magazine *Vokrug Sveta* (*Around the World*) his first science-fiction story *On the Moon*, which shortly afterwards came out as a separate book.**

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* This monograph which provides the working principle for powering a jet-propelled spaceship and gives a general idea of its design, was made public for the first time in 1954, in the second volume of Tsiolkovsky's *Collected Works*, put out in Moscow by the U.S.S.R. Academy of Sciences Publishing House.—*Ed.*

** Tsiolkovsky prepared the manuscript of this book in 1887 when residing in Borovsk; there is an inscription to the effect on the copy preserved in the archives of the U.S.S.R. Academy of Sciences.—*Ed.*

In this story, Tsiolkovsky introduces the reader to our nearest celestial object, our planet's satellite, the Moon. He does this on the basis of a thorough study of scientific sources and in a most fascinating way. He has lent his story the entertaining form of a narrative, in which a young astronomy enthusiast relates a dream he had while in a very deep sleep. The young man dreams that he and his physicist friend have been transported to the Moon. There they travel, take observations, perform scientific experiments and have many adventures. Ultimately, they are about to freeze to death during the long, cold lunar night..., when, fortunately, the young man awakes and decides to put down his dream in writing.

Tsiolkovsky gives an excellent description, packed with valuable information, of what confronts the first men to set foot on the Moon. Though the story was first published in the last century, it has stood the acid test of time and is still avidly read. It arouses particular interest today now that Soviet rockets have deposited the state emblem of the U.S.S.R. on the Moon and have so successfully photographed its hidden side, now that man will soon in reality fly to our closest neighbour.

In 1894 Tsiolkovsky completed another important piece of science fiction which he called "Changes in Relative Weight". In the first half he deals with the question of how to organise the study in interstellar space of changes in relative weight, describes in detail a special space structure for the purpose, which he dubs "star cottage" and tells us how to conduct experiments from it. However, this story has nothing as yet to say about how man will be able to strike out into space and build this "star cottage". Yet, in his *Free Space*, written nine years earlier, Tsiolkovsky already discussed manned space flight and provided the working principles of a jet-propelled spaceship. In the second half he imagines what one might chance to observe on various planets and asteroids. But not the whole of the manuscript was prepared for the press by

the author. There are a few less successfully written passages as, for instance, the conversations between the space traveller and the "inhabitants" of the celestial bodies in question. Tsiolkovsky polished up only parts of his manuscript, mainly his brief descriptions of imaginary voyages to Mercury and Mars, and the big asteroids, Ceres and Pallas. Tsiolkovsky's manuscript is being published for the first time in this collection.

In 1895 Tsiolkovsky completed a new science-fiction work called *Dreams of Earth and Sky and the Effects of Universal Gravitation*, which in book form was printed the same year in Moscow. Here for the first time, although cautiously and in a veiled form he discloses his ambitious dreams. After describing the majestic panorama of the Universe and emphasising the importance in our life of the universal law of gravitation, the author, by way of illustration, proceeds to tell of the fantastic occurrence, when undescribable chaos followed on the disappearance of gravity on the Earth. Then he develops the idea of the necessity of building an artificial Earth satellite, like the Moon, for scientific purposes. This is the first time that he uses the term earth satellite and also indicates that "the velocity required to give a centrifugal force that will destroy the Earth's gravitational pull should be not less than 8 kilometres a second", and that the altitude of the flight "beyond the atmosphere should be some 300 kilometres away", which incidentally was the estimated figure for the height of the atmosphere given in scientific literature at the time.

Tsiolkovsky also describes propulsion through space using the force of reaction, as well as "solar motors" to provide energy in space.*

Tsiolkovsky continued to develop his basic idea of inter-

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* Solar batteries were employed in Sputnik III which went up on May, 1958, to feed its radio equipment and the automatic interplanetary station fired at Venus in February 1961, also had these batteries.—*Ed.*

planetary travel, supplying more calculations. By 1895 he had already worked out the question of interplanetary travel in terms of mathematics, but did not publish his work at that date. In 1896 he began to write a science-fiction story called *Outside the Earth*, but, as he himself noted, the end of the year saw only nine chapters completed. In 1903 the magazine *Nauchnoye Obozrenie (Science Review)* at last published the first chapters of a large theoretical monograph called *The Exploration of Cosmic Space by Reaction-Propelled Apparatus*, the fruit of several years of work. This was his first scientific treatise giving the analytical side and also constructive proposals for a rocket with a drop-shaped body, its design and control. However, the secret police banned the magazine shortly afterwards, and Tsiolkovsky's article (only the first instalments had been published) passed unnoticed, particularly in view of the fact that he had not read the proofs, the various formulae were confused and there were other defects which made the meaning exceedingly obscure. The next instalment was published only in 1911 in the *Vestnik Vozdukhoplavania* (Herald of Aeronautics), an aircraft magazine published in St. Petersburg. At that time, the aircraft industry was just beginning in Russia and the first aircraft and aeronautics establishments were being set up. Consequently, the publication of Tsiolkovsky's article, being related to the entirely new science of astronautics that he himself had founded, produced a tremendous impression. He attracted a following which rapidly grew in number both in Russia and abroad, as also did the group of inventors of jet-propelled flying craft.

Tsiolkovsky, however, continued to experience great pecuniary difficulties as no assistance for scientific research was forthcoming. In 1916 the editors of the popular science magazine *Priroda i Lyudi (Nature and People)* suggested that he complete his science fiction work *Outside the Earth*. However, the magazine ceased publication, with only half the story printed, and Tsiolkovsky had his

manuscript returned. It was only under the Soviet power, that despite the desperate shortage of paper, Tsiolkovsky's friends and the local Natural History Society in Kaluga, managed to publish the book in 1920. Though the edition was extremely small, only 300 copies, the book achieved popularity even outside the Soviet republics.

In 1923 Prof. H. Obert published in Germany a monograph called *The Rocket in Cosmic Space*. After reading it Tsiolkovsky commented:

"Obert has much that is to be found in my *Outside the Earth*, including space-suits, the multi-stage rocket, the mooring of people and objects, the black sky, non-twinkling stars, mirrors (in universal space), light signalisation, the trans-terrestrial base, from which to launch out still farther, the voyage round the Moon, the 300-ton manned rocket, as well as the lunar studies and much more."

In birthday congratulations to Tsiolkovsky in 1929, Prof. Herman Obert quite definitely mentions the Soviet scientist's indisputable priority. "You kindled this fire," he wrote. "We shall not let it die; we shall try to realise man's greatest dream."

Outside the Earth is a glowing piece of science fiction brilliantly characterising Tsiolkovsky's work in this genre. The main characters are six scientists of different nationalities, who have clubbed together to conduct investigations at a castle specially built for the purpose in the Himalayas. They have at their disposal an army of engineers, craftsmen, and highly skilled workers, and all the necessary equipment. Tsiolkovsky symbolically christens them after world celebrities of the past. Thus the name of the Italian is Galileo, the Briton—Newton, the German—Helmholtz, the Frenchman—Laplace, the American—Franklin, and the Russian—Ivanov. This is more than a literary device; it reflects profound meaning of the story, namely, that man will most productively and expediently conquer space by working collectively, and not by the isolated effort of any one single country.

In Tsiolkovsky's team, it is the unassuming Russian scientist Ivanov who suggests a project which the others are at first inclined to view as utterly fantastic. However, they are won over, and enthusiastically embark on Ivanov's project to build a rocket, a jet-propelled spaceship, the working principle and design of which were described by Tsiolkovsky in 1883 in his monograph *Free Space*. Here he quite definitely calls his spaceship a rocket. *Outside the Earth* has a tone quite different from that of *Dreams of Earth and Sky*, in which he had been extremely cautious, making merely vague surmises. Now he boldly talks of his aims and how to accomplish them. With a sure hand he describes the inspired endeavours of the team of scientists and speaks in the greatest detail of the design of the first spaceship, the rocket itself, and its development. There follows a kaleidoscopic sequence of his dreams as a scientist. First comes the round-the-Earth flight, with the space travellers maintaining contact with their comrades in the castle by means of mirror and light signalisation, a method which Tsiolkovsky had already expounded in 1896 in the newspaper *Kaluzhsky Vestnik (Kaluga Herald)*. People on the Earth learn that man has already gone up into space, the first volunteers to migrate to other planets come forward, and preparations are made for the journey. Meanwhile the indefatigable Ivanov and one of the engineers prepare to fly to the Moon. Finally they do visit the Moon and use a special vehicle to travel about there, and they discover lunar animals.

In short, Tsiolkovsky here picturesquely describes his concept of man's future conquest of cosmic space.

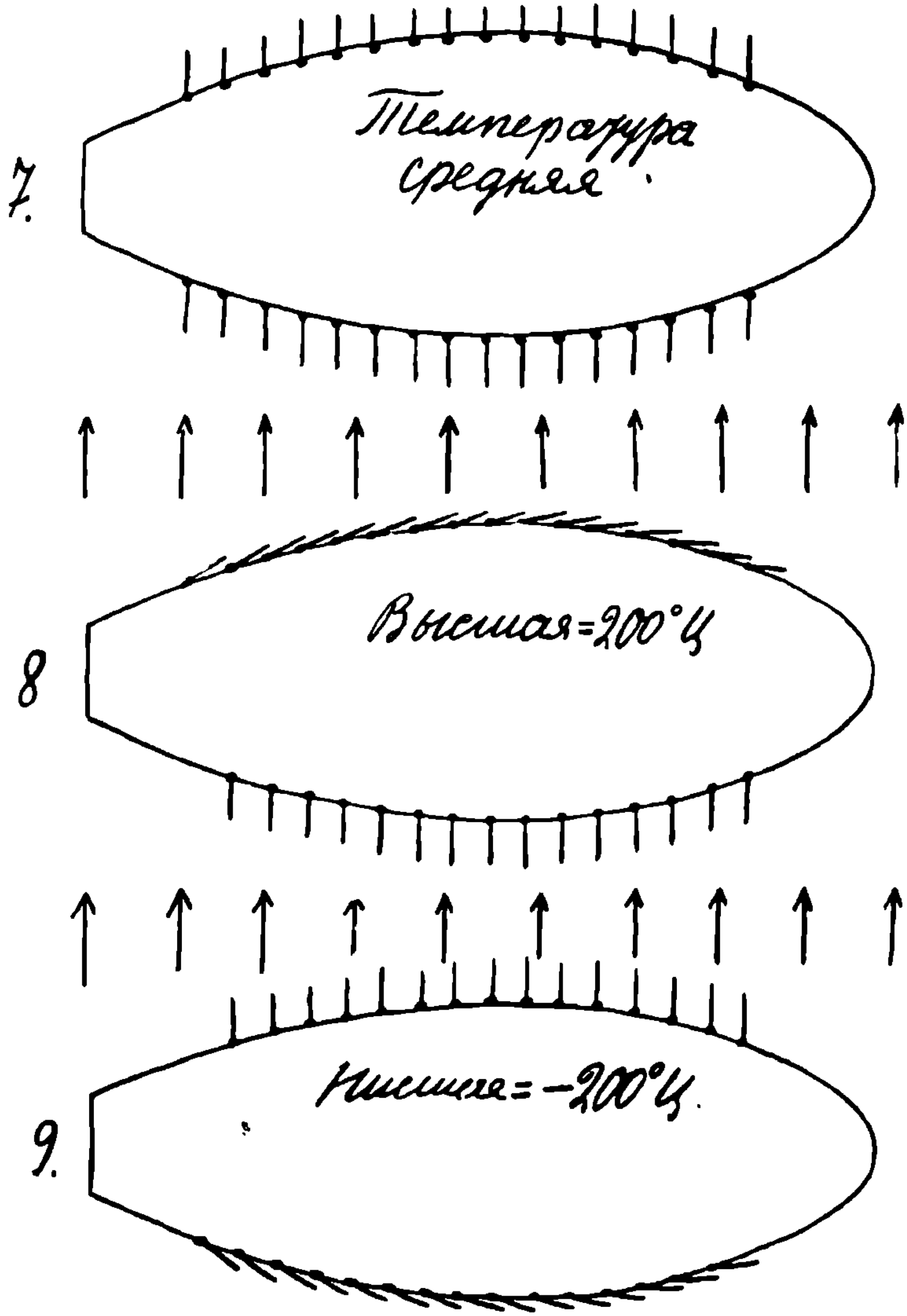
During the years that followed when Tsiolkovsky's researches had attracted the attention and support of the Soviet public and government, he elaborated these ideas in still greater detail in his *Aims of Astronautics*, published in 1929. Also a piece of science fiction, it captures and holds the imagination first because of the thoroughness with which the author describes the tremendous labour

man will have to perform in space during the centuries and millenia to come.

The important problems of the "biology of the future", which are inevitably connected with the evolution of living creatures in the process of "conquering solar space" are discussed in the two stories in this collection called "Living Beings in Space" and "Biology of Dwarfs and Giants". In the first he interprets from his own point of view the ways in which the propagation of life may take place in space. This short item in the form of a fantasy reveals what Tsiolkovsky thinks about vital processes, and also suggests that should the human race be compelled to migrate to airless space, it will be forced to alter its physical structure.

The second story, "Biology of Dwarfs and Giants" was taken and prepared for the press from a long manuscript called *Mechanics and Biology* (1920-21), which Tsiolkovsky did not complete. He began it in 1882, sending the first part to the great Russian physiologist I. M. Sechenov for his appraisal. Though unfinished, it interested Sechenov and he advised Tsiolkovsky to complete it. But only 40 years later was Tsiolkovsky able to do so.

The collection concludes with "Beyond the Earth's Atmosphere" and "Island of Ether". The first begins with references to experiments carried out in Germany in 1928-29 with automobiles and sleighs equipped with jet-propelled engines, and contains several highly original points about jet-propulsion technology. The "Island of Ether", on the subject of astronomy has, on the other hand, a peculiar flavour of its own. In Tsiolkovsky's house (now a museum) in Kaluga in the street which has been renamed in his honour, there is a glassed-in first-floor verandah, which served as a workshop for his inventions. A little door leads out of this verandah on to the slightly sloping roof of an adjacent shed. Tsiolkovsky and his family affectionately dubbed it "the door to outer space". In the evenings, when the weather was fair and the skies cloudless, Tsiolkovsky



From Tsiolkovsky's manuscript: "Space Travel Album" (1933). Sketch illustrates operation of the spaceship's shutters regulating the temperature. The arrows denote the direction of the Sun's rays.
7. Average temperature; 8. Higher —200°C; 9. Lower —200°C.

carried through the door his small amateur telescope mounted on a tripod, and out on the roof he observed the stars. His wife and neighbouring children who were frequent visitors, also enjoyed looking through the telescope. On these occasions Tsiolkovsky would gather them all around him and tell them the attractive, marvellous story of the constellations, planets, nebulae and shooting stars. "Island of Ether", which is now published for the first time, and gives a wonderful description of our Milky Way, is in form and content very much on the lines of the informal, moving science talks that Tsiolkovsky gave to his closest friends and acquaintances.

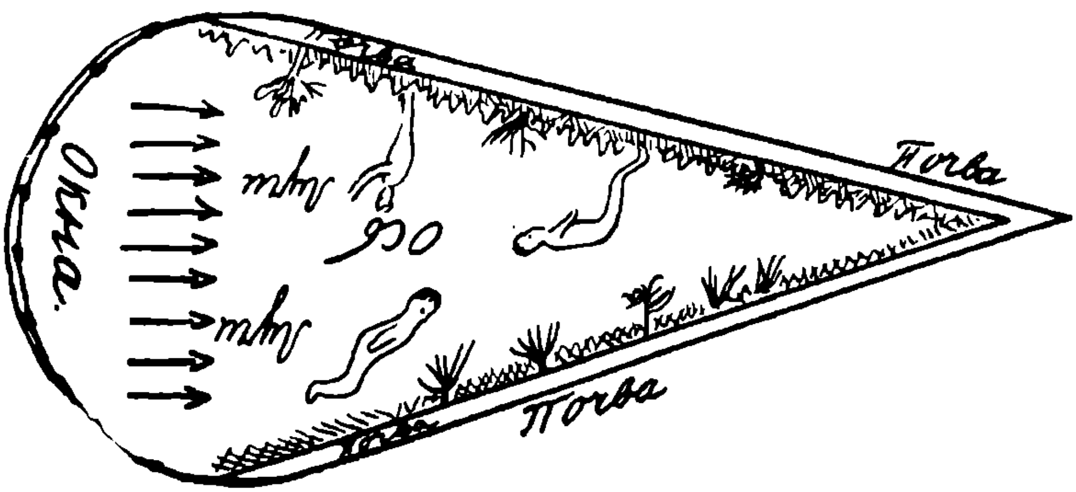
The supplement to the collection is Tsiolkovsky's article "To the Inventors of Reaction-Propelled Apparatus", which gives a comprehensive explanation of models of jet-propelled flying craft, which anyone can make without having to acquire any complicated tools or special materials. Drawings are also given. It should be noted that Tsiolkovsky was extremely interested in the handicrafts and modelling of the children at the local technical centre. It was in reply to the many questions addressed to him, as to which models were to be recommended as being safest to handle and how to construct them, that Tsiolkovsky wrote the above-mentioned article—which, too, is now published for the first time.

As one who strove tirelessly to advance mankind and its culture, and whose motto was "to help mankind forward at least a little", Tsiolkovsky was able to fire the minds of people by his inspired work. Now that we have entered the space age it will definitely be of great interest to read his writings.

After the establishment of Soviet power, Tsiolkovsky lived another 17 years, during which his works formed the basis of a broad movement to reach the stratosphere and investigate cosmic space. The number of his followers grew rapidly. When Tsiolkovsky had ceased to engage in further practical research, engineers V. P. Glushko and F. A. Tsan-

ее можно регулировать при жилищах удлиненных вдоль лучей солнца. Чем он длиннее, тем температура будет ниже.

54. Почва сбивается от вращения дальше от оси, так что лучи скользят вдоль ее поверхности и засаженных на ней растений. На дне же шара почва не удержится, растений там не будет и сила солнца будет пропадать даром. Однако при длинных конусах, наклон поверхности и почвы будет не велик, она останется на месте и растения будут освещены косыми лучами до самой оси. Достигнем и умеренной температуры и использования солнечных лучей



From Tsiolkovsky's manuscript: "Space Travel Album" (1933). Explanatory note on the sketch of a dwelling (hothouse) in Cosmos.

der, two of his closest followers, developed the first designs for jet-propelled engines on liquid fuel. The Soviet Union's first liquid fuel rockets were launched, and experiments made on the manufacture of jet aircraft. Meanwhile Tsiolkovsky devoted himself entirely to a voluminous treatise on jet engines.

With every new day, the ideas born of Tsiolkovsky's genius threw into bolder relief the majestic panorama of manned space conquest of the future. But ill health constantly interrupted his work.

On September 14, 1935, the newspaper *Pravda* published a document which made science history. This was Tsiolkovsky's letter to the Central Committee of the Communist Party of the Soviet Union. It read:

"... All my life I have striven by my work to help mankind forward at least a little.

"... I bequeath all my writings on aviation, rocketry and interplanetary travel to the Bolshevik Party and the Soviet Government as the true leaders of man's cultural progress. I am sure they will successfully consummate this work.

"I am yours with all my heart and mind, and with my last sincere greetings I remain always

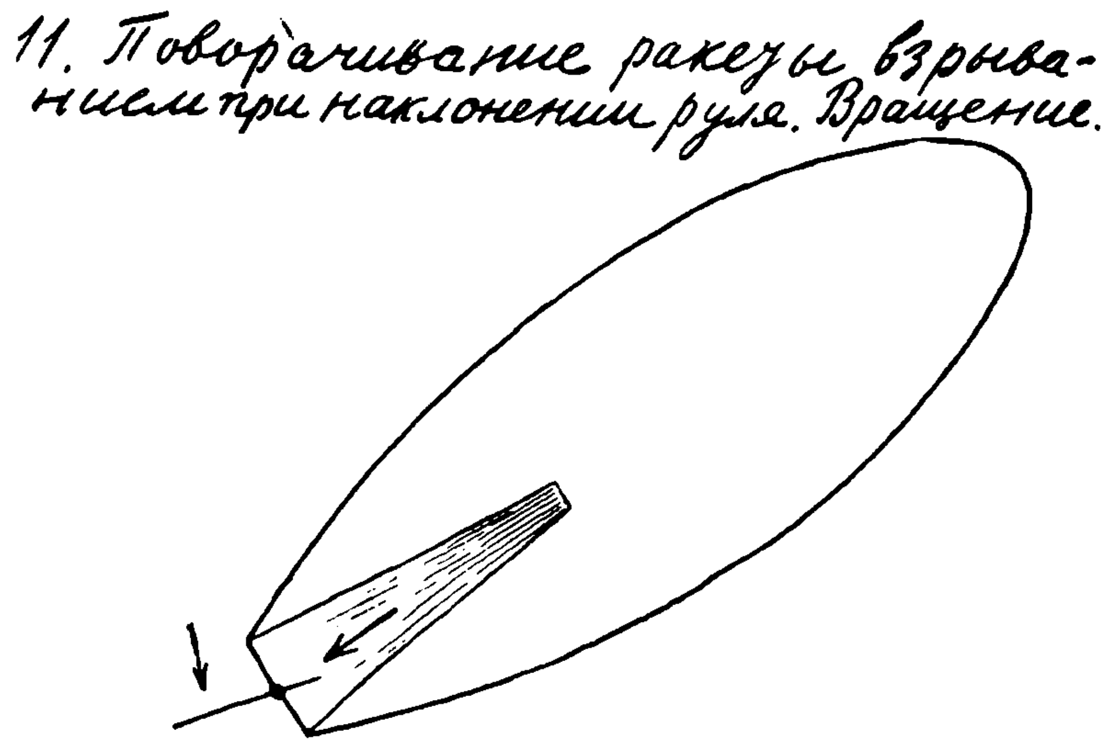
Yours,
K. Tsiolkovsky"

On September 19, 1935, the great Russian scientist, Konstantin Tsiolkovsky, passed away.

His pupils and followers, Soviet scientists, engineers, technicians and factory workers, have brought to life and fully realised the ideas advanced by Konstantin Tsiolkovsky in the field of rocket flight and interplanetary communications.

Soviet achievements in the discovery and conquest of cosmic space, which have ushered in a new era in the history of mankind, are universally known today.

On September 17, 1957, a few days after the U.S.S.R. Academy of Sciences and other scientific establishments



From Tsiolkovsky's "Space Travel Album" (1933). Sketch shows how gas rudders operate in a jet-propelled spaceship.

and public organisations had celebrated the centenary of Tsiolkovsky's birth, a monument to him was unveiled in Leningradsky Prospekt in Moscow and the foundation stone of another monument was laid in Peace Square in Kaluga. On October 4, in the same year, the Soviet Union launched its sputnik, the first artificial earth satellite ever produced. The event impressed the whole world. Following this, the Soviet Union, and later the United States, sent up a series of artificial satellites varying in size and weight. Soviet rockets reached the Moon and photographed its reverse side and several rockets were put into orbit round the Sun. In 1960, a Soviet spaceship carrying experimental animals successfully returned after a journey of several hundred thousand kilometres in space round the Earth. In 1961, an Earth-Venus automatic interplanetary station was launched from the heavy sputnik.

If one compares the content of Tsiolkovsky's science

fiction with the terse TASS account of the Soviet automatic interplanetary station, one cannot fail to note the familiar terms, for instance, "gyroscopic transducer", which Tsiolkovsky used in describing the first project of a spaceship in his monograph *Free Space* written in 1883. (See the supplement for the diagram.) In his *Dreams of Earth and Sky*, written in 1895, what are now known as solar batteries are called solar motors. In the diagram for the unfinished manuscript *Space Travel* (1934), Tsiolkovsky demonstrates temperature control inside the rocket by means of shutters.

Light signalisation is mentioned time and again in *Outside the Earth* (1920), only it is done not by means of a sodium vapour cloud, as in the case of Soviet space rockets, but with the aid of bright electric searchlights.

In the present-day designing, building and launching of sputniks and space rockets, Soviet scientists and engineers have undoubtedly invented immeasurably more than Tsiolkovsky did. Nevertheless, it was the realisation of all the "conjectures" of the genius who founded the theory of jet propulsion and interplanetary travel, which has brought his country the tremendous achievements and unfading glory of this age. Lenin was indeed right when he defined imagination as a quality of the greatest value.

SUPPLEMENT I

TO INVENTORS OF REACTION-PROPELLED MACHINES

(Dated April 28, 1930)

Both adults and children send me hundreds of projects for reaction-propelled means of locomotion. To all of them I can give the following reply.

The essence of a direct-flow engine is that one matter is ejected rightwards, while the projectile moves leftwards by virtue of the recoil. In order to get the smallest possible store of explosives that will not overburden the vehicle, the ejection velocity should be of the greatest possible order, since this velocity imparts the same speed to the vehicle. Explosives or fuels, by combining with the reserve oxygen compound, produce jet velocity from 1,000 to 5,000 metres a second. These are what should be used.

When the explosion occurs, part of its energy is imparted to the apparatus, while the other part of its energy is expended in the gas jet. To achieve a decent ratio in the use of chemical energy, the projectile's velocity should not differ greatly from that of the jet of gases. Let us suppose that the velocity of the gas jet is 2,000 m/sec. Then, to achieve high efficiency in the use of the explosives or explosion-producing elements, the vehicle must have a velocity of close on 2 km/sec. Probably one kilometre would be enough.

But are such velocities possible on our roads and in the air?

In the case of a velocity of 1,000 m/sec the resistance of the onrushing air stream should be more than

100 tons per square metre. Actual conditions are still worse.

Indeed, with a speed greater than that of sound, the air in front of a plane condenses and becomes an insuperable obstacle (a stone wall, as it were). In addition, this speed would break every wheel to smithereens and make the roads impossible. At a low speed the unevenness of roads can be tolerated, but at a high speed it becomes unbearable.

If resistance in the air is insuperable, it is still more so in water. Consequently even speed-boats are no use.

What is to be done, then? Are reaction-propelled, direct-flow engines to be put to no purpose at all?

We do not say this. We can get out of the difficulty by giving the vehicle the streamlined, elongated shape of a bird or fish, and by travelling through the air, instead of along solid earth or across water.

We thus, willy-nilly hit upon the idea of a *fast* reaction-propelled aeroplane. But even this, however, beautiful in its shape, cannot work up a velocity of several kilometres a second in the lower, dense strata of the atmosphere. We must fly our aeroplane in the rarefied strata of the atmosphere, to the stratosphere.

Our reaction-propelled aeroplane or rocket plane thus becomes a rocket-propelled stratoplane. This is a complicated task that is too difficult for the knowledge, powers and erudition of children. A reaction-propulsion research institute takes care of all that. Let us leave this work and the likely achievements to the institute.

What can we children do? We can make some highly interesting toys. Unfortunately, they have all been made before and even patented as inventions of supposedly serious import. We can only reproduce them. However, they will be instructive for grown-ups and children alike.

Here is a list of them:

1. *A gun-boat.* The gun, either of the spring, gas, or gunpowder type, ejects a cannon-ball, and the boat shoots in the opposite direction.

2. *A boat with a horizontal fountain.* A water-filled cylinder is mounted on the stern of a small vessel. Water flows from it, through the lower aperture, into the pool below. The recoil compels the boat to move (until the cylinder runs dry).

3. *A steamer.* A small tin boiler, heated by methylated spirit, is installed on a toy boat. The water boils, turns into steam which escapes through a very narrow aperture in the stern propelling the steamer. The effect will be much greater if the steam is ejected under the water through a tube. But this will no longer be a pure type of reaction-propelled machine.

4. *A similar reaction-propelled automobile.* Here, to achieve greater success, we need a small ordinary rocket instead of the boiler. In ordinary conditions, the force produced by the steam will be found to be insufficient to propel the vehicle.

5. *A gas boat.* Instead of the heated water-filled boiler we can use an inflated rubber bladder. The air escaping from its aperture will compel the boat to move. A football bladder can be used.

6. *The flying inflated balloon* that everyone knows.

7. *An ordinary rocket* equipped with a chamber and manned by toy travellers, for the sake of effect.

8. *A propellerless plane with a rocket.* A long light tail (calico will do very well) should be fitted to its rear to keep it steady in the air.

Besides providing amusement, these toys may also serve as a stepping-stone to the building of reaction-propelled stratoplanes.

SUPPLEMENT II

IS THIS MERE FANTASY?

I was asked some 10 years ago to have my story *Outside the Earth* adapted for the screen. But since this proved such a complicated affair, the enterprise was laid aside.

Only now has the Mosfilm studios, in the talented person of V. N. Zhuravlyov, firmly decided to produce the film *Cosmic Journey.*

I was 17 when I first dreamed of the possibility of travelling beyond our own planet. In 1895 I wrote my *Dreams of Earth and Sky*. It was published by the nephew of the famous Goncharov and was then twice reprinted by the State Publishing House under the title of *Gravity has Vanished.* In the first years after the Revolution, I took up the subject seriously. The fantastic story called *Outside the Earth* (1918) reflected this work.

The mathematically elaborated theory of a reaction-propelled vehicle appeared already in 1903, at first in Filippov's philosophical journal *Nauchnoye Obozrenie (Science Review)* with small circulation, and several years later in the *Vestnik Vozdukhoplavania (Herald of Aeronautics)* (1911-13). Then several publications appeared in separate editions and in magazines. From 1913 onwards my works gained recognition also abroad.

There is nothing that engrosses me more than the problem of overcoming terrestrial gravity and of making flights into space. I seem to devote half my time and energy to this problem. I am already 78, yet I still continue to compute and design reaction-propelled machines. The things I have thought about and the ideas that have surged through my brain! This was no longer fantasy, but exact knowledge based on the laws of nature; new discoveries and new compositions were in the making. But I was also attracted to science fiction. Many times I essayed the task of writing about space travel, but wound up with a stronger fancy for exact considerations and switched to serious work.

Science-fiction stories on interplanetary trips carry new ideas to the masses. All who work on these lines, work well, arousing interest, promoting the working of the brain, and training up people who are attracted by the idea of grand projects, and who will work in this field in the future.

What can be grander than to master the full energy of the Sun, which is 2,000 million times greater than the energy the Earth gets from the Sun! What can be more splendid than to find an outlet from the tight little corner of our planet, to be in close communication with outer space and to give people a way out of the cramped position on the Earth and a chance to throw off the shackles of gravity!

Cinema has a wider appeal than books. They are more graphic and closer to nature than a mere description. This is the supreme artistic level, especially now that the cinema is coupled with the sound-track. I think it very heroic of the Mosfilm studios and Comrade Zhuravlyov to have undertaken to produce the film *Cosmic Journey*. I must say I am extremely pleased with this work.

What is my own view of journeys into space? Do I believe in them? Will man ever be able to accomplish them?

The more I worked, the more were the difficulties and obstacles of all kinds that I encountered. Until recently, I supposed that hundreds of years would be necessary to effect flights at astronomical velocity (8-17 km/sec). This was confirmed by the poor results achieved both here and abroad. But the uninterrupted work carried out in recent times has shaken my pessimistic views: methods have been found which will produce amazing results in a few dozen years from now.

I hope that the attention our Soviet Government pays to industrial development in the U.S.S.R. and to every kind of scientific research will justify and bear out these, my own, expectations.

(*Komsomolskaya Pravda*,
July 23, 1935)

Kaluga

SUPPLEMENT III

PAGES FROM A YOUNG MAN'S NOTEBOOK

In 1878-79, while living in Ryazan, Tsiolkovsky worked on the problems of interplanetary travel. Preserved in his archives at the U.S.S.R. Academy of Sciences is a small

18-page exercise-book (relating to that period). It was in connection with this work that he experimented at that time, using home-made contraptions, chiefly a rotary machine.

Tsiolkovsky used experimental mice, chicks and insects to ascertain the effect that acceleration of gravity has on living organisms. In this schoolboy exercise-book, the future scientist jotted down his considerations regarding the advisability of carrying out other experiments and research, at the same time making sketches and diagrams of new apparatus for the purpose.

The notes in this exercise-book were the rough drafts of *Free Space*, the monograph he wrote while living in Borovsk, where from 1880 he was arithmetics and geometry master at the local school.*

The few pages from the exercise-book published in this collection reflect some of Tsiolkovsky's ideas, which he later developed in his books in a strictly scientific and most fascinating form.

Editorial Board

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* The monograph was first published by the U.S.S.R. Academy of Sciences Publishing House in 1954 in the second volume of Tsiolkovsky's *Collected Works*.—*Ed.*

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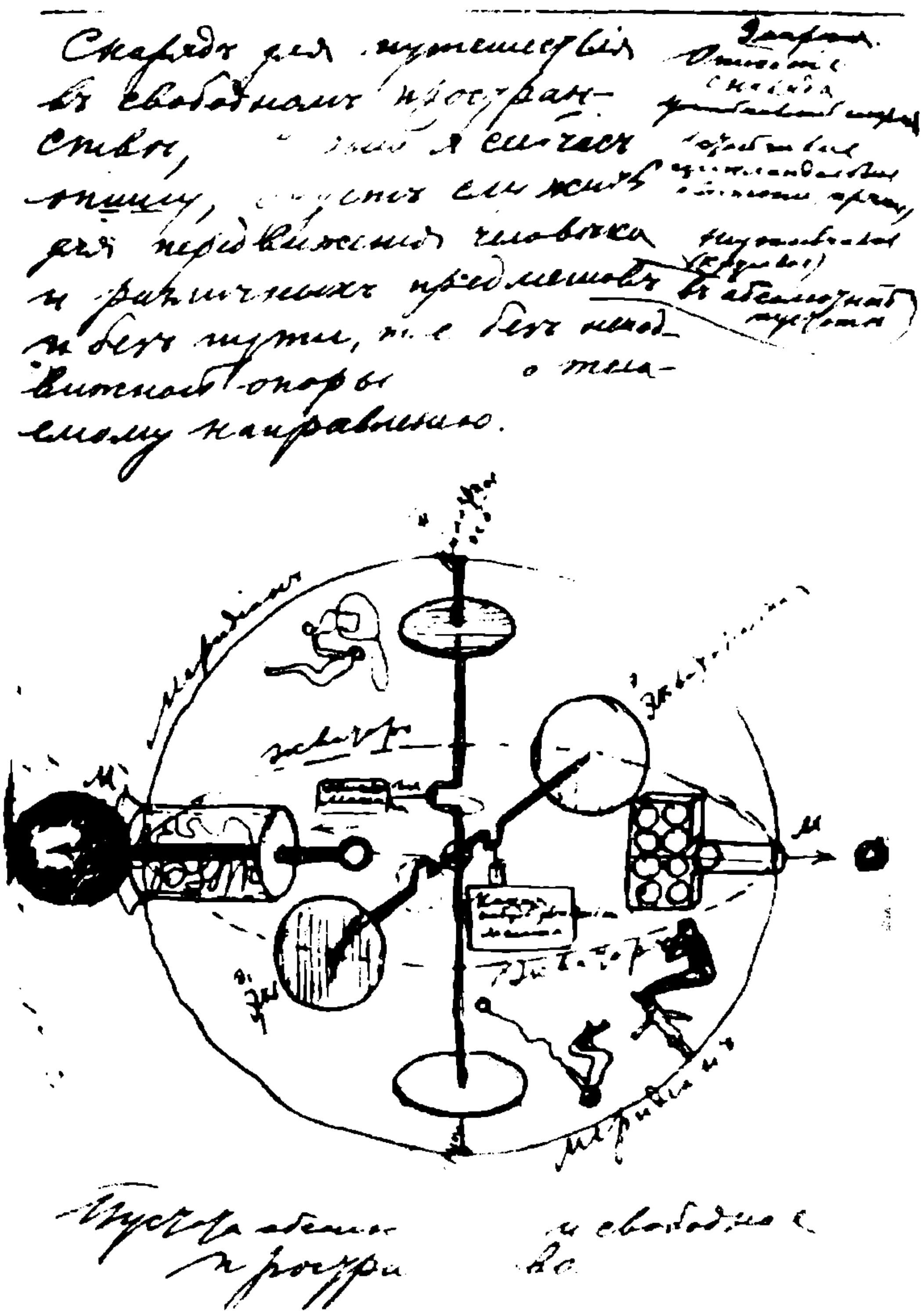
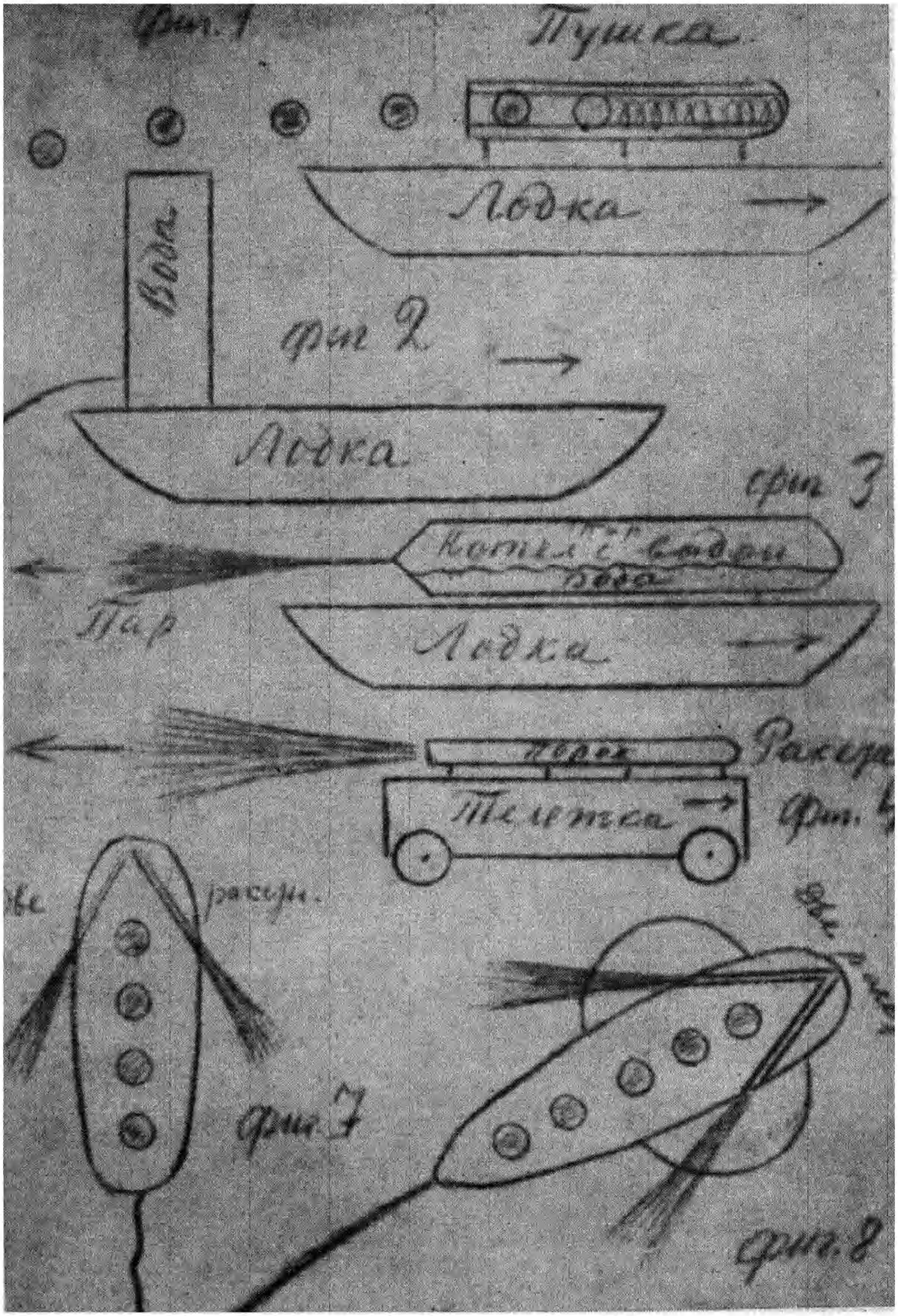
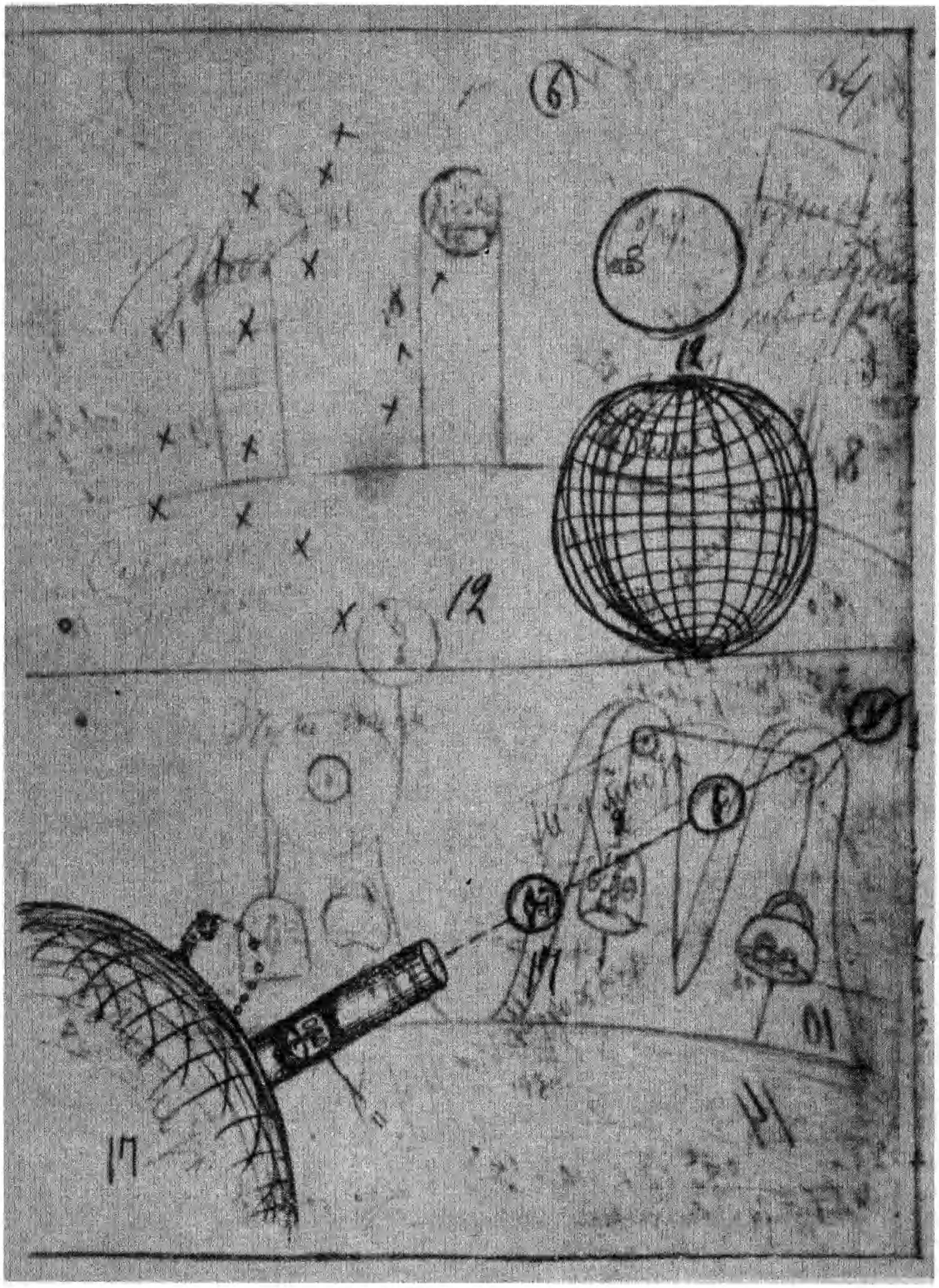


Facsimile of a page from the manuscript of Tsiolkovsky's *Free Space* (1883). Sketch of cross-section of jet-propelled spaceship. Right: Cannon firing spherical projectiles and propelling the vehicle through space with its recoil (reaction). Centre: Gyroscopes, the revolving of which can change the position (orientation) of the spaceship in space. The sketch is dated March 9, 1883 (Old Style)

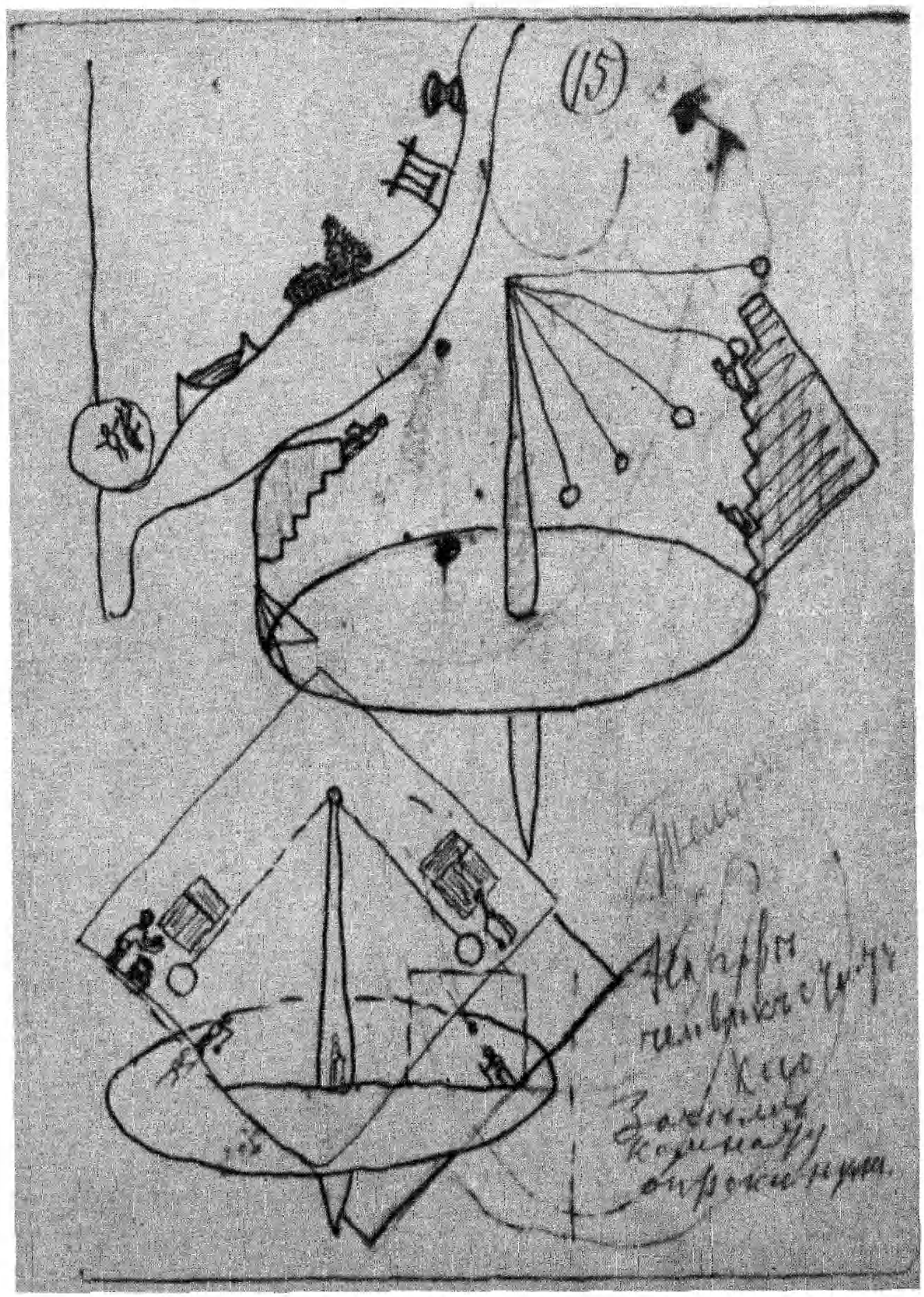


Tsiolkovsky's sketch for "To Inventors of Jet-Propelled Machines"

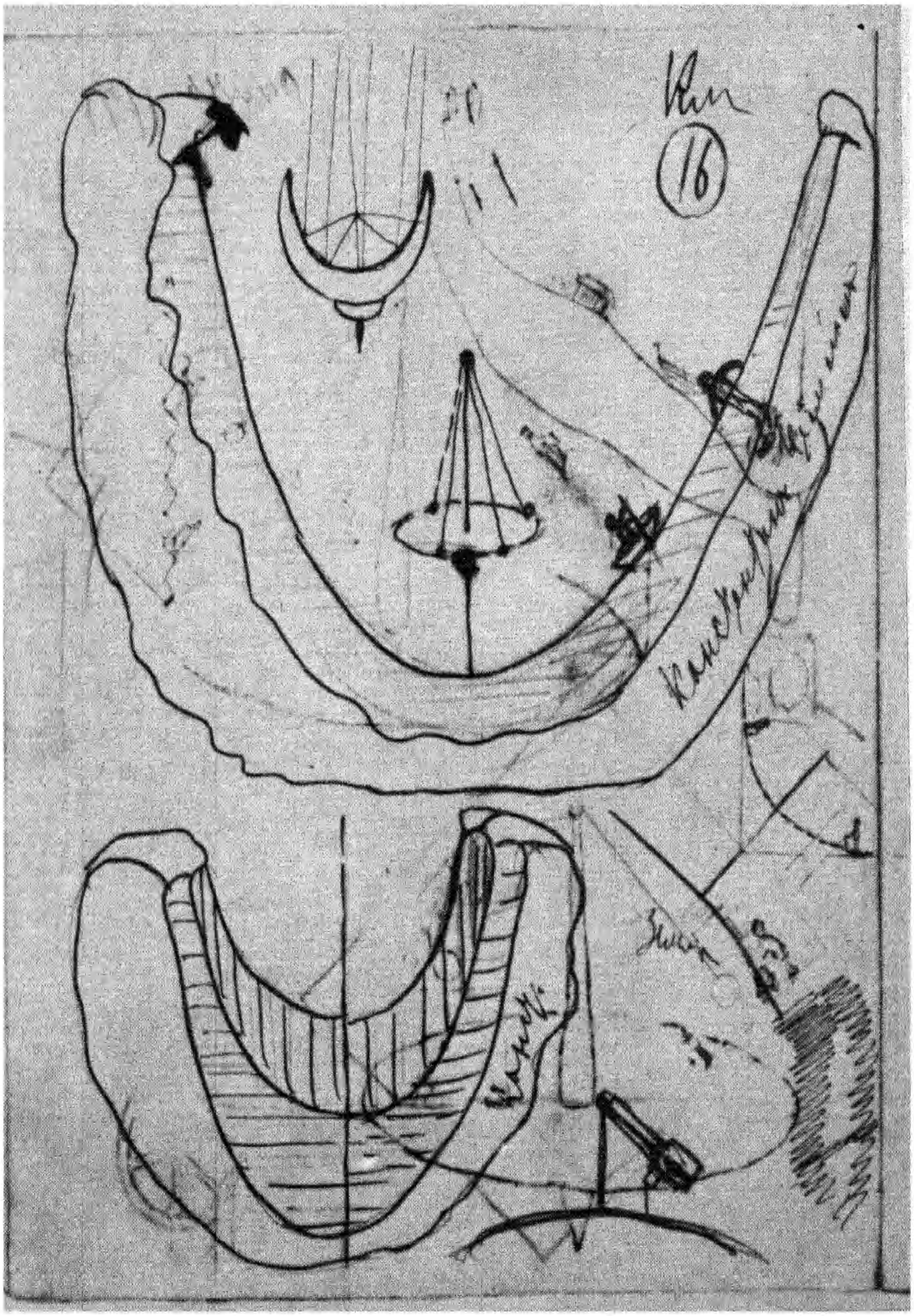


Projected or falling projectile has no weight. In a carriage that is just starting to move or is about to stop, a horizontal gravity is produced, which added to the terrestrial gravity, results in an inclined relative gravity. The same takes place in the cannon-ball ejected by horizontally-mounted gun

For Supplement III

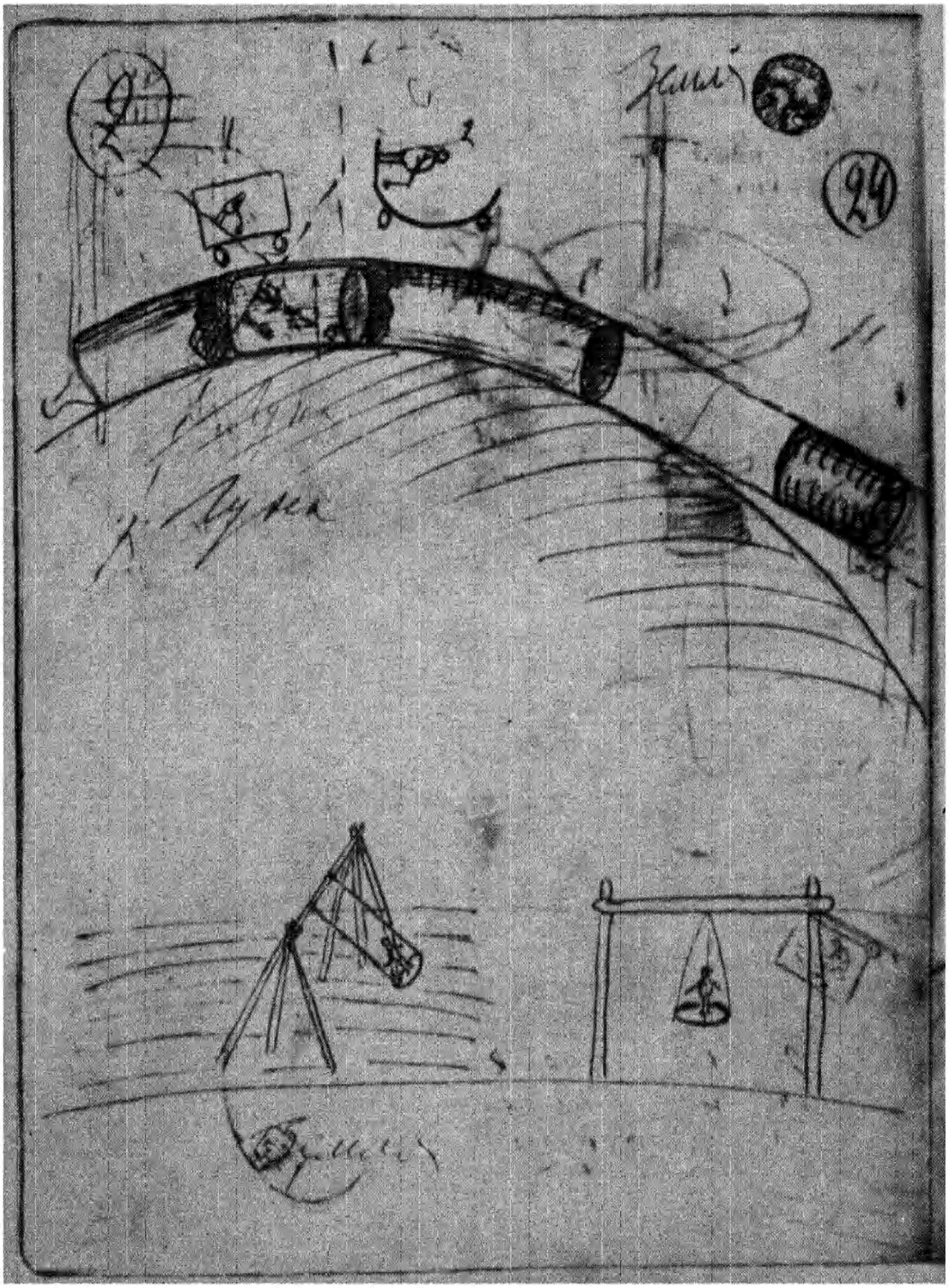


Two persons standing in a room at right angles to each other

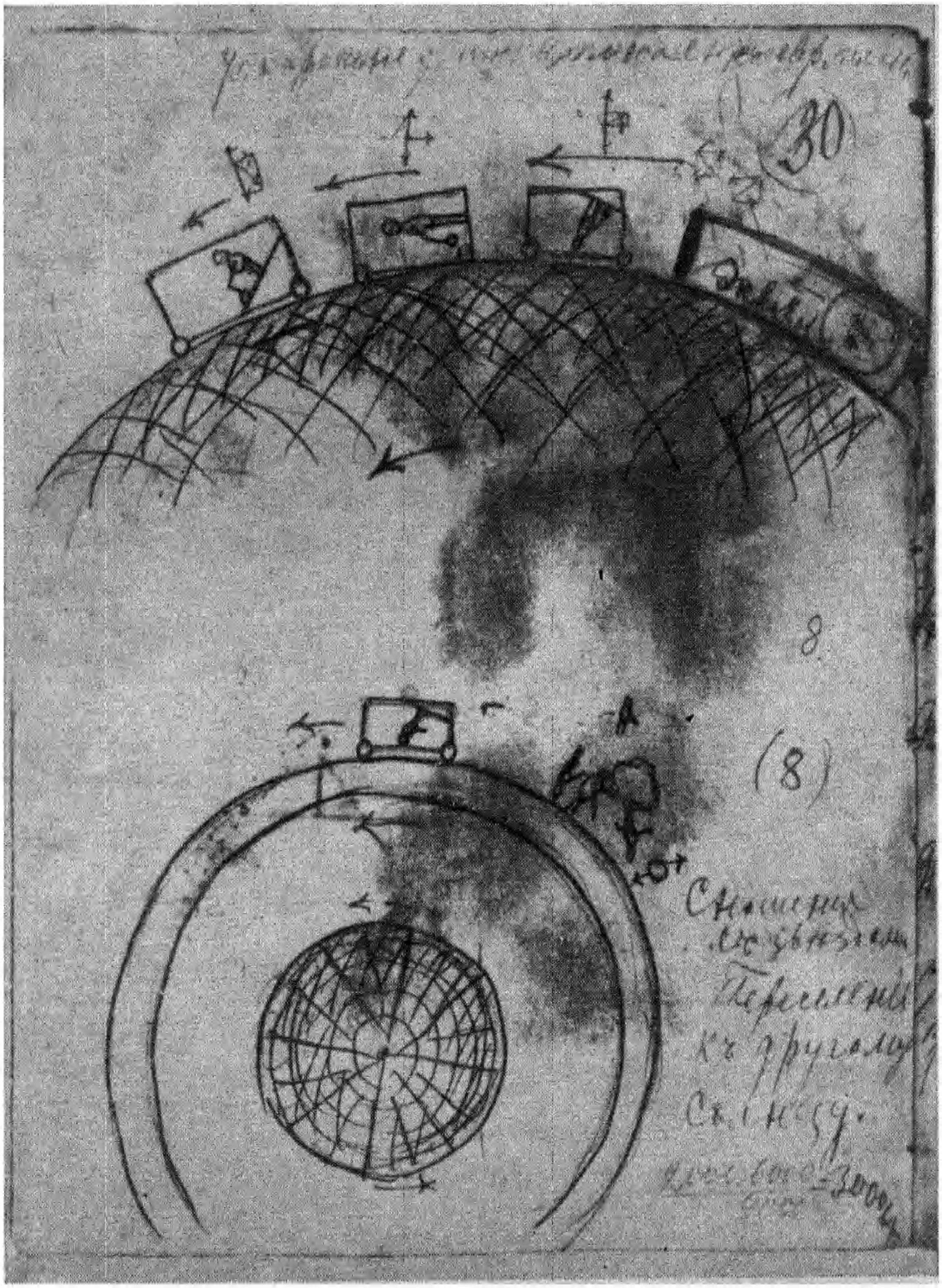


Liquid assumes the form of rotation (of the body)

For Supplement III



Phenomena occurring in the cannon-ball of a bow-shaped gun, and on swings



In gravity-free space curvilinear motion produces relative gravity proportional to the arc curvature and the square of the carriage's velocity

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